# DECADE

***Domestic Equipment and Carbon Dioxide Emissions***

**Second year report**
**1995**

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# EXECUTIVE SUMMARY - DECADE SECOND YEAR REPORT

## DECADE - Domestic equipment and carbon dioxide emissions

DECADE deals with the electricity consumed in lights and appliances in British homes. Data have been collected and analysed for the period 1970 to 1994 and projected forwards to 2020. The DECADE project combines information about the ownership and use of domestic electrical lights and appliances.The trends cover changes in technology, behaviour and demographic factors, to give a detailed breakdown of electricity consumption and the resultant emissions of carbon dioxide.

Statistical modelling has been used to analyse the data and the careful selection and application of the appropriate techniques is one of the main reasons for improved confidence in the findings. A major advance in 1995 has been the development of a model of the stock of appliances in British households to replace crude assumptions about average equipment in use. The characteristics of each major appliance group are combined with detailed analyses of appropriate policy options to provide a powerful policy impact assessment tool. DECADE thus has a useful analytical and predictive capability.

The model is now operational and provides the first detailed study of domestic appliance consumption in the UK. This is a complex area to model - there are over 13,000 data cells covering 26 major appliance groups. It can be difficult for policy makers intuitively to assess the need for or the likely impact of policy initiatives. One of the main uses for DECADE, and its strength, is to provide a sound basis for discussions with government, manufacturers, retailers and consumers about the likely effects of a range of current and proposed “Market Transformation” policy initiatives in this area. The European Commission, Department of the Environment and Energy Saving Trust have already used DECADE to inform policy development.

The DECADE project is advancing the theoretical understanding of the value of end-use (or bottom-up) models, undertaking research into the way in which consumer behaviour and values can be predictive of environmental actions, and is developing a model (PRIME) to consider the reactions of manufacturers, retailers and consumers to policy scenarios.

### Historical trends in consumption: 1970-1994

A quarter of all electricity in the UK is now used in domestic lighting and appliances. This level of consumption is 7-8% higher than previously estimated over the whole period 1970-94. Electricity consumption in domestic lights and appliances has grown steadily since 1970 at an annual rate of 3% pa and by 1994 represented nearly three-quarters of all uses of electricity in the home.

The historical growth in electricity consumption for domestic lights and appliances has resulted from increasing numbers of households, more appliances, higher levels of usage, and these have only been partially offset by technology that improves the energy efficiency of the equipment. The major users - lighting, cold, wet and brown appliances and cooking - consumed 93% of the electricity in 1994, though their ranking changed over the period.

Compared to previous studies, most of the revisions have come from lighting: annual household consumption has been increased in all years, and from 1970 to 1994 this resulted in a near doubling of annual household consumption from 375 to 729 kWh. The revision, which is still tentative, comes from both a better model of lighting and data from measured surveys. Even this substantial increase in UK domestic lighting is lower than that found in Denmark, where 100 households averaged 900 kWh pa.

Life-cycle analysis of cold appliances shows that 3/4 of energy is in use, rather than in construction or transport. This is the same for most major appliances. Other environmental impacts are frequently linked to energy consumption: for instance less hot water in a wet appliance requires less energy for heating.

The net effect of all these trends is that each household is using 50% more electricity for domestic lights and appliances in 1994 than in 1970, despite the fact that each household contains fewer people: in 1970 an average of 2.9 people used 2000 kWh pa, whereas by 1994, 2.5 people used 3000 kWh pa.

**Patterns of use**

The functional grouping of appliances has provided useful insights and understanding. For instance, a decline in oven and hob use has been more than offset by increased use of small cooking appliances (eg toaster, kettle, microwave). Another functional grouping is the wet appliances: increased use of the washing machine results in more clothes going into the tumble dryer (where one is owned).

Some of the increase in energy use results from households obtaining a higher level of energy services. For instance there are more light bulbs per house, a larger volume of refrigerated or frozen space and more hours of television are watched. In other cases, there has been a significant increase in energy consumption to provide minor increases in the standard of service and benefits to consumers. The main example is the use of standby facilities (to facilitate remote control of TVs and videos). Sometimes behavioural changes have resulted in less energy consumption: since 1970, the average wash temperature is $10^{o}$C lower resulting in a 10% saving in the energy that would have been used in washing machines.

**Technology and ownership trends**

New appliances are generally more efficient than earlier models, for similar standards of service. The biggest improvements in energy efficiency have come from cold appliances and in televisions, where power demand in 1994 is a third of the level in 1970. The introduction of fan-assisted ovens has reduced consumption and cooking time by up to a quarter. These benefits can be offset by the way the equipment is installed. If the casing is too tight around a cold appliance in a fitted kitchen, the energy consumption can increase by 10-90%. The benefit of a hot-fill washing machine depends upon the design of the plumbing system in the house and the distance from the hot water tank.

The appliances sold in shops vary considerably in their energy efficiency and this cannot (without energy labels) be detected by the consumer. For identical levels of service, the electricity consumption of the most inefficient appliance is more than twice that of the most efficient one for cookers, fridge-freezers, washing machines, tumble dryers and dishwashers.

Ownership of most appliances increased, except where there was a substitution: for instance fridge-freezers replacing refrigerators. TVs are in 98% of households and the average house now owns an average of
1.7 TVs; second videos are now becoming widespread. The ownership of more efficient technology spreads slowly with only 16% of households having a CFL in the UK in 1994.

**Projected trends in consumption**

The DECADE business-as-usual figures show consumption continuing to rise, but more slowly, at less than 1% pa. The main cause is the rise in household numbers between 1994 and 2020 from 23.5 to 28.5 million. These projections indicate greater growth than that modelled by the Department of Trade and Industry. The DTI consider that electricity consumption in appliances will remain at the 1991 level until 2005; according to DECADE it will be 10% higher. Both the DTI and DECADE project growth in demand from 2005 to 2020.

Ownership levels of home computers, dishwashers and tumble dryers are expected to continue to rise. Multiple ownership of TVs and videos - and a further increase in viewing hours - coupled with increased levels of lighting in the home are other reasons. In addition, new equipment includes satellite and cable TV equipment, and home office equipment, such as fax machines and answerphones. Usage levels of most appliances are projected to remain at present levels. Not all technology developments result in greater energy efficiency. Some expected (and already visible) trends will result in higher consumption in future. These include: more standby functions (clocks and standby on microwaves), frost-free freezers and fridge-freezers (which may use 200-300 kWh more compared to conventional freezers), wide screen TVs (14% more electricity per appliance).

With existing policy initiatives, the greatest improvements in the efficiency of the appliances bought are expected to come from the cold appliances (where the underlying rate of change is expected to be reinforced by the existing mandatory energy labels and expected minimum standards); televisions and VCRs (because of manufacturer initiatives) and lighting (consumers will switch to CFLs).

By 2020 household electricity consumption is projected to decline to 2900 kWh pa per household, largely as a result of the improved efficiencies of cold appliances.

**Potential savings**

The economic and technical potential scenario is based on proven technology that would provide economic benefits to consumers. Further design options would become economically justified if current equipment prices were to fall, or if energy and water prices were to rise. The ETP scenario does not include changes in usage or consumer behaviour. These have not been modelled because of the uncertainty of possible savings, so the ETP scenario does not represent the lower limit on consumption.

If government policies could access the full ETP by 2020, there would be a further 39% saving in electricity, below the BAU, and this would be worth £75 per household in reduced annual running costs. Two-thirds of this is in the cold appliances and lighting, although at least 25% of the electricity consumed by each major appliance group could be saved with economic benefits to consumers.

**Policy issues**

If overall electricity use is to be stabilised or reduced, the improvements in energy efficiency would have to be substantial to offset the cumulative effect of additional households.

Policies will be most effective in combination: education programmes of consumers and retail staff to support labels; rebates to encourage purchases of the most efficient appliances and minimum standards to ensure that the least efficient equipment is no longer sold. The appropriate combination of policies will be specific to an appliance and will depend upon the rate of technological change, the spread of efficiencies already on the market, the level of consumer awareness and a range of other factors.

The effect of information and incentives is difficult to predict, although there are a few pilot studies that provide indicators. With strong support from the retail staff and management, the Scottish Hydro-Electric stores showed a 19% improvement in the efficiency of cold appliances stocked over one year. Generally in the UK, the labels on cold appliances have not been supported by information to retail staff and consumers, so there has been less effect.

The complexities of modelling interacting policies that have differential effects over time and on sectors of the population has led to the development of PRIME - a policy response-interaction model for energy. This will provide the basis for judging the impacts of policy inititiatives on manufacturers, retailers and consumers. The model will separately assess the effect of one or more policies on the number and type of appliances being purchased, the extent to which each machine is used and the efficiency of the models manufactured. This innovative approach will still depend upon expert judgements and specified parameters.

There are 144 million households in the European Union, making it a larger market than the United States of America. European policies define the standard of appliances for all countries exporting to the EU and, therefore, have implications far beyond the fifteen member states. The Czech Republic, Poland, Argentina, Russia and Thailand are all countries known to be watching European decisions on minimum standards. Once the industry manufactures to a higher standard, in order to have access to the European market, it will also be able to improve the standard of appliances offered in other markets, to the benefit of all.

**Behavioural research**

The more efficient use of energy is influenced by the choices people make about appliance purchases and the way the equipment is used. In order to access these savings, an understanding is needed of how and why people make the decisions they do. Research into behavioural issues is designed to illuminate this process, and identify whether it can be influenced and, if so, in what way.

The preliminary findings of a study of recent fridge-purchasers found only 10% of consumers are well-informed about environmental issues, though 90% are ‘very’ or ‘quite’ concerned about the environment. This demonstrates a knowledge gap as accurate information is a strong influence on willingness and ability to conserve. There is a relationship between an understanding of global warming issues, educational levels, a willingness to take responsibility for environmental care and a positive attitude to domestic energy efficiency.

After energy labels were introduced, the DECADE survey found that only 37% reported seeing the label. Of these, two-thirds would have liked more information, either on the label, through the sales staff, or on a poster in the shop. The biggest demand was for information on running cost implications. People whose work or educational background is focused on scientific and technical types of activity were more receptive to the energy label.

When consumers notice the label and can obtain information, one third are influenced ‘a great deal’ or ‘quite a lot’ in the purchase they subsequently make. There are correlations between background factors (socio-economic group and age), contextual influences (local community attachment and early learning), levels of knowledge on environmental issues and actions such as response to an energy label. A clear correlation was found between the extent to which people said they were influenced by the label and the energy efficiency of the refrigerator they bought.

Between 1994-5, there was a 19% improvement in the efficiency of the cold appliance models stocked in Scottish Hydro-Electric showrooms in a pilot study of the effect of energy labels. This resulted from changed consumer purchasing patterns, magnified by the Buyer’s policy, after the labels were introduced and supported by both an informed and enthusiastic retail staff. Sales staff are generally seen as the most useful source of information when purchasing household appliances, but a survey in Oxford found retail staff had not been trained about energy efficiency or provided with educational material to support the energy label on cold appliances.

**Carbon dioxide emissions**

Carbon dioxide emissions from domestic lights and appliances peaked in 1987 and by 1994 were already 22% lower, due to the lower carbon dioxide content of the present fuel mix for electricity generation (mainly more nuclear, with some gas-fired plant). Further growth in gas-fired electricity generation is anticipated to result in falling carbon dioxide from domestic lights and appliances until 1999. Emissions will then rise continuously until 2020 when they will be nearly as high as the 1987 peak.

If all the ETP can be accessed, by 2020 the savings in carbon dioixide emissions would be more than 5 MtC pa. Without new policy initiatives, carbon dioxide emissions from domestic lights and appliances will be as high in 2020 as they were in 1990.

## CHAPTER 1: INTRODUCTION BRENDA BOARDMAN

### 1.1 THE IMPORTANCE OF DOMESTIC APPLIANCES

DECADE deals with the electricity consumed in lights and appliances in British homes. Data have been collected and analysed for the period 1970 to 1994 and projected forwards to 2020.

In the United Kingdom, electricity consumption across all sectors has risen since 1970. In the home, electricity is used for space and water heating, as well as for lights and appliances. Of the rising national consumption of electricity, an increasing proportion is going into domestic lights and appliances (Table 1.1 and Figure 1.1). In 1970 the proportion used by domestic lights and appliances was 20%, whereas by 1994 it had increased to 24%. Therefore, in the UK, the use of electricity in domestic appliances is a substantial and growing proportion of all electricity use and thus a major contributor to carbon dioxide emissions.

**Table 1.1 Electricity consumption, UK 1970 and 1994 (TWh)**

| | 1970 | 1994 |
|---|---|---|
| Domestic lights and appliances | 39.3 | 71.0 |
| Domestic sector | 77.0 | 100.6 |
| All sectors | 192.4 | 288.5 |
| Domestic lights and appliances as a % of total electricity consumption | 20 | 25 |

Sources: DUKES 1978:29 and 1995:103 and DECADE
Note: The definition of the equipment included by DECADE in lights and appliances is given in Appendix C.

The figures for electricity consumption in lights and appliances given in Table 1.1 represent one of the findings of this study. They indicate that electricity consumption in domestic lights and appliances is higher than previously thought, for the whole period 1970-94 (Shorrock *et al* 1992:6). Since the total for all domestic electricity consumption is known from household bills, historic consumption cannot exceed the amount of electricity that has been sold to householders. As a result of the DECADE-demonstrated increase in historic electricity consumption in lights and appliances, there should be a concomitant reduction in electricity consumption in either space or water heating or both, so that the total sold to domestic consumers remains the same. This reassessment of domestic electric space and water heating has not been undertaken yet, so there can be no revisions to the totals. The separate lines shown in Figure 1.1, therefore represent the traditional judgement on space and water heating and the DECADE revision for lights and appliances. These do not add up to the correct total of electricity sold for the UK; the GB figures are approximately correct.

Even allowing for the change in geographical coverage (from GB to UK), there has still been an upward revision in the total electricity consumption in lights and appliances of about 7-8%. Whilst large, this is within the confidence limits that can be attached to the total consumption figure. This uncertainty is created by the volume and quantity of the data, which was lower in Run 1. There has been additional data collection and more sophisticated statistical analysis for Run 2, increasing the level of confidence in these latter figures.

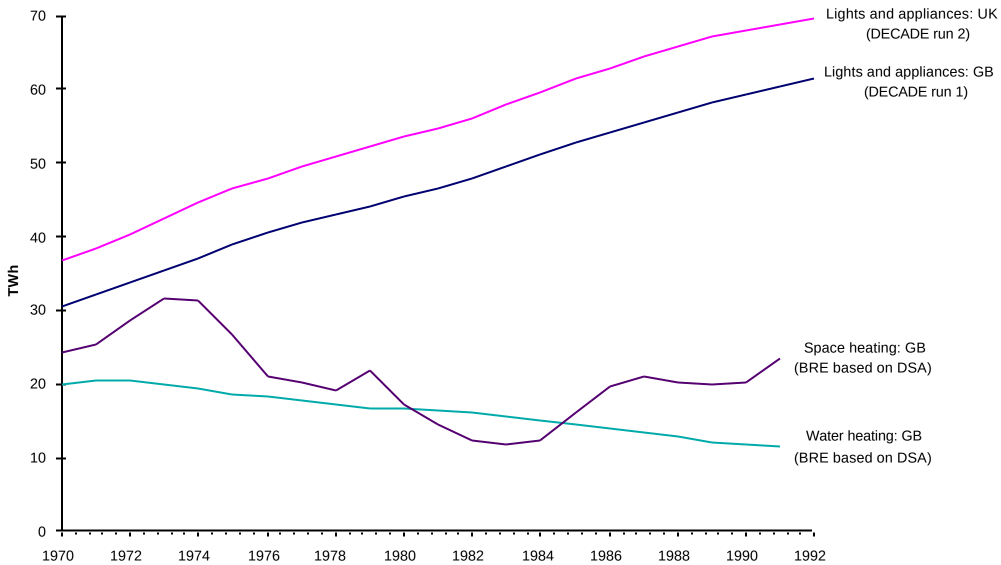


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**Figure 1.1 Domestic electricity demand, by major end use category, 1970-1992**
Sources: DECADE team estimates; Building Research Establishment (BRE)3; Domestic Sector Analysis (DSA) from the Electricity Association

Past research into the use of energy in the home has focused on the variety of fuels that are used for space and water heating, which still represent about 75% of all energy used in the home. The main fuel is now gas. Whilst heating is still important, there are several reasons why more attention needs to be paid to the other uses of energy in the home. First, as homes become better-insulated, reductions in the domestic sector from the energy used in appliances will be the main remaining opportunity for savings in households. Secondly, the turnover in the stock of appliances is relatively rapid as most equipment has a lifetime of 10-15 years. This enables improvements to spread more quickly than, for instance, improvements to the Building Regulations. Thirdly, with the present average generating mix, electricity is the most polluting fuel in terms of carbon dioxide emissions per unit of delivered energy and therefore policies to reduce these emissions have to focus on electricity use. With a few exceptions (hot fill washing machines, tumble dryers and gas hobs), appliances are electricity specific - there are limited fuel substitution options. Therefore, any strategy to curb carbon dioxide emissions is likely to include the more efficient use of electricity in appliances.

Consumers do not want to buy energy. They want the energy services that are obtained when the fuel - usually gas or electricity - is converted in a piece of equipment into the light, warmth or cold food storage that is wanted. For the householder, the size of the bill and quality of the energy service provided is as important as the quantity of energy used. Gas is cheaper per unit of delivered energy: for example, at the meter in Oxford in November 1995, gas cost 1.54p and electricity 7.5p for a kWh (inclusive of VAT).

Although the average household uses 40% more energy for water heating as is used in lights and appliances, the majority of the water is heated by the cheaper fuel - gas. Therefore, using their lights and appliances costs the average household nearly twice as much as their hot water. Few families realise the significance of lights and appliances in their weekly budget. Nor do they realise that the more efficient use of this equipment could produce useful savings in the fuel bill, without any drop in the standard of service obtained.

## 1.2 POLICY CONTEXT

### 1.2.1 European policy

International concern about global warming has resulted in the signing of the Climate Change Convention and Agenda 21. In the European Union (EU) the commitment to stabilize carbon dioxide emissions at the 1990 level, by the year 2000, has resulted in a range of initiatives, with a strong emphasis on the more efficient use of energy. The main focus, which includes many of the following policies, is the EU SAVE programme - Specific Actions for Vigorous Energy Efficiency.

Energy labels, eco-labels and energy efficiency minimum standards are all EU initiatives to encourage the more efficient use of energy in domestic appliances (Table 1.2). The energy star labels cover office equipment that is also used in the home. The effectiveness of these policies will depend as much upon the reactions of consumers and manufacturers as on the character of the policies that are enacted. These and other policy initiatives are discussed in more detail in Chapter 2, in the relevant appliance chapters and Chapter 9, which covers some of the behavioural responses to policy.

**Table 1.2 Policy on energy efficiency in domestic lights and appliances, EU 1995**

| Policy instrument | Appliance | Timetable |
|---|---|---|
| Energy labels | Cold appliances ** | Mandatory from 1.1.95 |
| | Wet appliances ***<br>Light bulbs | Mandatory from 1.4.96<br>Drafted |
| Energy star labels | Computers, printers, faxes, photocopiers | Drafted 1995 |
| Eco-labels | Washing machines and dishwashers | November 1993, under review 1996 |
| | Cold appliances **<br>Lighting | Under discussion<br>Under discussion |
| Minimum efficiency standards for new appliances * | Cold appliances ** | Decision due December 1995 10% cut in efficiency of average new model sold. Implementation date to be decided |
| | Wet appliances *** | Shortly after, perhaps voluntary |

* Minimum efficiency standards for cold appliances have not yet been set by the Commission, as expected, but the Dutch and Danish Governments retain their right to go ahead unilaterally with their own, perhaps more rigorous, standards if there is no Europe-wide scheme in 1995.

** Cold appliances are refrigerators, fridge-freezers and freezers.

*** Washing machines and tumble dryers; dishwashers are not included yet as there is no performance test procedure for them.

All of these initiatives demonstrate the emphasis that is being placed on improving the efficiency of domestic appliances. Progress to date has been slow, despite the best efforts of DGXVII, the Energy Directorate in Brussels and the Dutch and Danish Governments. The importance of the approach is being recognized and supported by manufacturers, though the speed of reaction varies with the appliance market: the manufacturers of audio-visual and computer equipment are accustomed to rapid technical change and are more responsive to energy efficiency initiatives. The manufacturers of the white goods (refrigerators and washing machines) appear to be more cautious. In countries like the Netherlands, Germany and Denmark, consumers are energy literate and have been demanding the more careful use of resources - particularly energy and water - for several years. The cumulative effect of the policies, of ‘market pull’ from consumers and ‘market push’ from manufacturers could soon be substantial, though at the end of 1995, the whole process has yet to gain real momentum.

In order to inform these policy initiatives and prepare for others, the European Commission supports several research studies. The DECADE team contributed to the second study by the European Group for Efficient Appliances (GEA 1995) on the three wet appliances (washing machines, tumble dryers and dishwashers), a project completed in June 1995. Work has started on two European projects to look at standby consumption in televisions and video cassette recorders and secondly, at the electricity used by domestic stored-hot water systems. The DECADE team are participating in both of these studies. Other work, to consider the issue of joint labels for both gas and electric equipment (eg washing machines, tumble dryers and hot water systems) is also progressing.

### 1.2.2 United Kingdom policy

The UK Government’s contribution to the climate change debate has changed substantially since the first major analysis in 1992. Energy Paper 59 stated that, if Britain is to comply with its Rio commitments, there would be a need for further reductions in carbon dioxide emissions, equivalent to 10 MtC by 2000 (EP 59 1992). Improvements in the efficiency of appliances in the UK were expected to contribute 0.5 MtC by 2000 out of this total (Cm 2427 1994, para 3.39), with further contributions from other SAVE initiatives in the domestic sector, particularly minimum standards. The UK Government stated that it expected these standards to be progressively strengthened:

> ‘The objective of the first stage of the introduction of minimum standards is to give, by 1997, an average improvement in the efficiency of domestic electrical appliances of 10%, worth £100 million a year of total electricity savings to UK domestic consumers alone, by removing the most inefficient appliances from the market. A further toughening of standards to yield a 40% total improvement by the year 2000 is proposed’ (Cm 2427 1994, para 3.39).

Subsequently, the short-term targets have been revised with the publication of Energy Paper 65 (EP 65 1995). Britain is expecting to achieve stabilisation of carbon dioxide emissions in 2000, largely because a substantial proportion of electricity will come from gas-fired generation rather than coal (Appendix A). In addition, domestic electricity consumption is expected to drop slightly and the government has assumed that:

> ‘Appliance related electricity demand remains broadly flat at its 1991 level until 2005 across all scenarios as higher appliance ownership is offset by improvements in appliance efficiency resulting in part from the 1994 Climate Change Programme measures. Beyond 2005 further improvements in the efficiency of the existing stock of appliances becomes more limited and the introduction of new appliances leads to modest long-term growth in demand’ (EP 65 1995, para 4.8).

The Climate Change Programme included Value Added Tax on domestic fuel (now at 8%), together with the establishment of the Energy Saving Trust (EST). The effectiveness of these measures at encouraging energy efficiency has not been established. EST lighting programmes are covered in Chapters 2 and 7.

The British concern for more efficient appliances has, like the rest of Europe, yet to gain momentum, though steady progress has been made. The whole process of changing the market for energy efficiency is more formally known as Market Transformation. This is an evolving set of objectives, with the Department of the Environment's definition in November 1995 given in Appendix D. The initiatives that comprise Market Transformation are described in Chapter 2. At the end of 1995, the Energy Efficiency Office of the Department of the Environment changed its name to the Environment and Energy Management Directorate. The new title reflects a focus on the wider environmental impacts of products and services: resource depletion, water and land contamination, and so forth. The extent to which different environmental impacts are given priority will depend upon public concern and political priorities. Not least amongst these will be the British Government's suggestion that the next Climate Change Commitment should be for the developed countries to achieve by 2010 a 5-10% reduction in greenhouse gas emissions below 1990 levels (*The Guardian* 9 March 1995).

## 1.3 THE DECADE PROJECT

### 1.3.1 Objectives

This report represents the end of the first tranche of the DECADE project, covering the period 1.1.94 to 31.12.95. Further funding has been secured for the 18 months until the end of June 1997. The DECADE project is providing a framework for analysis of policy options on the reduction of carbon dioxide emissions by the development of an end-use model of electricity used in domestic appliances. The project started from two of the EU SAVE Programme's objectives for 1993:

- to build on the new appliance labelling legislation;
- to evaluate consumer responses to different ways of conveying the energy efficiency message.

The DECADE project addresses these objectives quantitatively and qualitatively. The project both models domestic appliance electricity use and assesses the influence of cultural and behavioural factors on determining demand. The DECADE project is a combination of:

- a database comprising over 13,000 entries, each of which is annotated for source, definitions and other parameters. The majority of the data refers to the UK (subdivided by country), but this is supplemented by data from a wide range of European and other studies. Even so, the quality of the data varies substantially. Ownership information is of a generally high standard, whereas there is little detail on how appliances are used;
- a set of modelling methodologies that use sophisticated statistical techniques to establish historic use and to project trends. Due to a lack of UK data, the results sometimes have to be fine-tuned on the basis of judgements about other information, for instance technical efficiency trends in Germany or the way the appliance is used in Denmark;
- a detailed analysis of relevant policy initiatives and the factors that have determined their success or failure. The main focus has been on policies introduced by Government, rather than the utilities;
- a study of the factors that affect consumer purchase and use of appliances and, in particular, are predictive of a concern for environmental issues and energy efficiency. This work combines both an extensive literature search and an in-depth survey of people who bought a cold appliance in Oxford since the introduction of labels (Chapter 9);
- these two qualitative studies are being used to support the Policy Response-Interaction Model for Energy (PRIME - Chapter 10). This module is being developed to provide the basis for assessing both the cumulative impact of policies over time and to identify separately the effect on manufacturers, retailers and consumers;
- for each of the five main appliance groups, the data, statistical techniques, policy experience and consumer knowledge have been combined to give a clearer indication of the projected growth until 2020 and potential for energy reduction.

The DECADE project has the capacity or the potential to inform discussion, for domestic appliances and lights, on the:

- impact of various policies and strategies, either generically or specifically to an appliance group;
- general effect of new design standards for manufacturers, either in the UK, Europe or in total;
- implications for energy distributors and generators, both in terms of total demand or at peak hours;
- levels of fuel-related emissions, particularly carbon dioxide, but also the oxides of nitrogen and sulphur dioxide;
- opportunities to reduce a broader range of environmental impacts, for instance water consumption, the resources used in appliance manufacture, the ability to design for recycling, either through life cycle analysis or other methodologies.

An important further dimension is the underlying theoretical debate. The DECADE project is extending research into three areas:

- the role of end-use models in comparison with the contribution from econometric models. An end-use model starts with data on individual actions on purchase and use and aggregates these into a picture of total consumption. It is not directly related to the main drivers of econometric models, for instance the state of the economy. Both models have a role to play in judging the effect of policy factors that are external to the household: in one case these are linked to the economy (income and prices generally) and in end-use models, the link is with policies based on behaviour and technology. In the past, most reliance has been placed on econometric models, particularly to indicate the need for additional energy supply. These studies tend to ignore the role of policies focused on individual actions or the potential for technical change.

- the links between the behaviour of an individual and that person's values. The factors that affect consumer response to policy are poorly understood and then only in a tentative, qualitative way. It is difficult to predict what level of impact on energy efficiency can be achieved through effects on behaviour, but DECADE is conducting both a qualitative analysis and developing a quantitative methodology to give the model a predictive capacity.

- the development of a predictive tool for policy analysis which incorporates behavioural factors. This has taken the form of a computer implementation of a theoretical model (PRIME: Policy Response-Interaction Model for Energy). PRIME simulates the flow of policy-induced change through a network which represents connections between societal groups (eg manufacturers, retailers, and consumers). The progress of more than one policy at a time can be modelled. Insights provided by PRIME into the behavioural responses resulting from such policy interactions promise to be particularly useful.

### 1.3.2 First year

The research during the first year of the project was published in DECADE 1994, the First Year Report (copies can be obtained from the ECU). This provides a full background on the methodology adopted and achievements in the first twelve months of the project. The text has not been duplicated in this Second Year Report. The main finding in DECADE 1994 was summarised in the first run of electricity consumption in lights and appliances, known as Run 1 (repeated in Figure 1.1). The other major finding was that the data on ownership levels are good, but that the trends in usage and technology are poorly documented.

## 1.4 FOCUS OF DECADE DEVELOPMENT IN 1995

The preliminary findings from 1994 were refined in 1995. The major revisions include enlarging the geographical coverage from Great Britain to the United Kingdom, through the addition of information from Northern Ireland to that already obtained for England, Wales and Scotland. Often, because of limited data, the extension was achieved by a straight multiplication based on household numbers, but specific Irish findings were included where known. Two other influential developments and one major extension need to be examined in some detail. These are:

- revisions to the 1991 census data by the UK Government;
- development of a stock model by the DECADE team, to reflect the profile of the appliances owned in the UK at any one time;
- projections of future energy use until 2020 under two different scenarios, together with an assessment of appropriate policy initiatives.

### 1.4.l 1991 census revisions and implications

A major influence on future energy demand comes from the total number of households and the likely levels of appliance ownership. Even with near universal ownership, for instance of cold appliances, televisions and washing machines, there will be additional consumption for each extra household. Over the time horizon of the DECADE project (to 2020) there will be significant demographic changes in the UK which will affect both household numbers and composition.

As a result of the 1991 census, population projections for the UK were revised upwards significantly. These revisions are continuing because of the acknowledged census under-enumeration which has now been incorporated into the official projections. A further complication is that some researchers have estimated that the 1991 census may have missed counting one million people, but this has not yet been incorporated into official population projections, nor into our figures for this report.

The numbers of households are a powerful driver of demand for energy, so these revisions and others that may follow have substantial impacts on projections of energy demand. The numbers used in DECADE are shown in Table 1.3.

**Table 1.3 Population, household size and household numbers, UK 1971-2021**

| Year | Population (000s) | Average persons per household | Number of households (000s) |
|---|---|---|---|
| 1971 | 55 638 | 2.9 | 18 424 |
| 1981 | 56 165 | 2.7 | 20 667 |
| 1991 | 57 649 | 2.5 | 22 929 |
| 2001 | 59 719 | 2.34 | 25 010 |
| 2011 | 61 110 | 2.22 | 26 961 |
| 2021 | 61 980 | 2.12 | 28 646 |

Sources: OPCS 1993, CSO 1995, DoE 1994 & 1995; DECADE

Several trends are resulting in this change to more and smaller households. These include different attitudes to marriage and cohabitation (so that fewer children are born and their parents are older), higher divorce rates and people living longer. The increase in household numbers, therefore, is coming predominantly from single-person households, with a continuing decline in the number of traditional families. Single-person households have historically had lower levels of appliance ownership than the average, as they usually have lower disposable income (whether young or old). In addition, previous generations of older people did not have an expectation of high appliance ownership. In future, both pensioners and young people are going to be more accustomed to appliance ownership, more prepared to purchase new equipment and, perhaps, be more able to afford it. This will provide a further impetus for high ownership levels.

The main demographic factors over the next 25 years affecting the DECADE model will be:

- population growth and falling household size leading to further increases in household numbers;
- a large increase in the number of single-person households;
- and a significant rise in the number of 'older' households.

These factors are used in formulating scenarios for the DECADE model.

### 1.4.2 Stock model

A major advance in the DECADE project has resulted from the way in which the data have been modelled, particularly in the development of the profile of the stock of appliances that already exist in people's houses (explained in more mathematical detail in Appendix A). This has been made possible with the accession of sales, ownership, technical and usage data through time.

Figure 1.2 shows one example of the stock model, for fridge-freezers. Each band represents the stock of appliances in UK households bought in a particular year. This number declines over time, as individual appliances break down or are discarded, with the average lifetime depending on the appliance. The lifetime of a fridge-freezer is 16.5 years, but there will still be appliances in the stock in 1994 that were bought in 1977. The lifetime of an electric kettle is shorter, but longer for free-standing cookers. In any one year, the sales of new appliances are made up of those that replace old appliances and those that add to the stock as they go to first-time buyers. As a result the number of households owning that appliance increases over time, and the profile, in this example, rises.

There are good data for ownership and sales of the major appliances and these can be rationalised to provide an estimate of the lifespan of the average appliance. Measured data on electricity consumption in people's homes can be used to validate the stock model, since the model estimates consumption in the home from other data sources. The stock model also permits a more detailed analysis of policy by taking into account the time it takes to replace the stock. Thus, the development of the stock model has considerably strengthened the detail and internal consistency of the DECADE modelling process, despite the known data weaknesses.

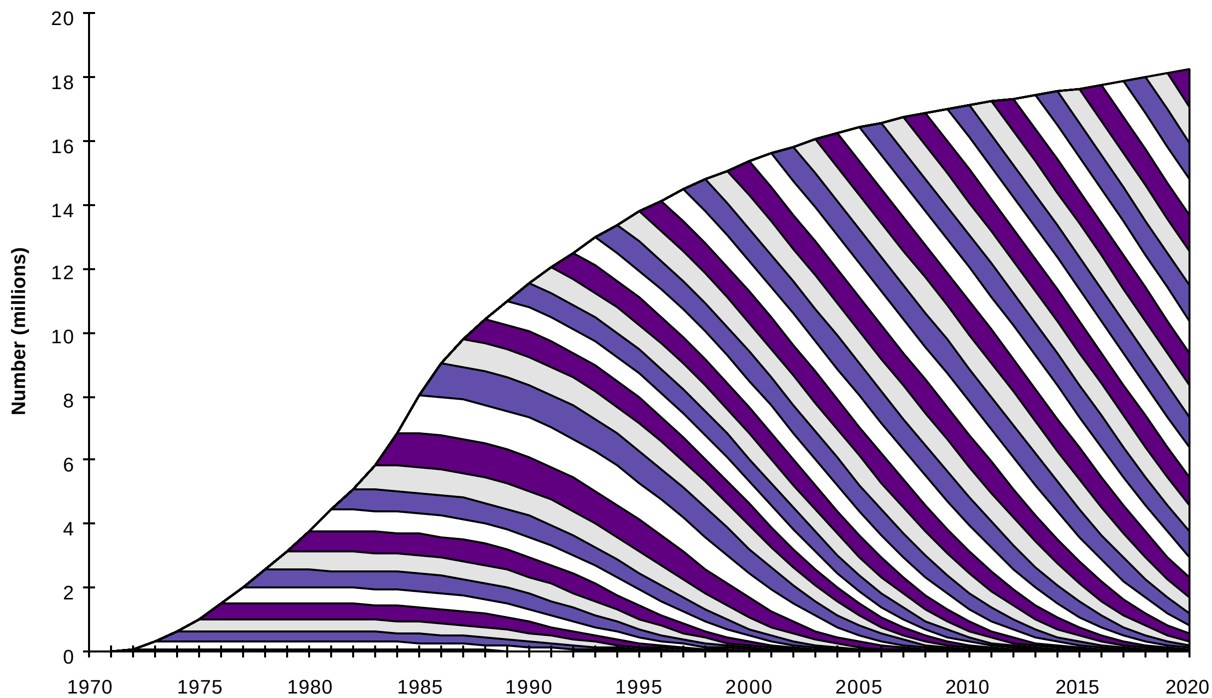


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**Figure 1.2 Profile of the stock of fridge-freezers, UK 1970-2020**

A further benefit of these profiles is that the energy efficiency of the stock can be modelled using the efficiency of the average model sold in that year. These are based on limited performance figures for old appliances and have not incorporated the effect of deterioration - the appliance is still assumed to be as efficient as the day it was purchased. Refining the efficiency levels modelled is an important task of the next DECADE project. The stock model provides the basis for estimating the rate at which new levels of efficiency would permeate into the stock. The additional detail obtained from the stock models has increased confidence in the overall totals. Where measured consumption and sales data are available, the cross-comparison between the different data sets allows for internal validation and confirmation. For these reasons, the team have confidence in the revised historical data and the projections for the future.

### 1.4.3 Scenarios and policies

The DECADE approach to scenarios is built on a detailed analysis of historical evidence for each specific appliance, in the context of a functional approach to usage. This is most clear with cooking, where the trends for use of a cooker interact with the growth in ownership and use of electric kettles and microwaves. Similarly, if a household is using the washing machine more often this will have implications for both the amount the tumble dryer is used (where one is owned) and, perhaps, for the amount of ironing. The categories of appliances studies and the details on the equipment covered are given in Appendix C.

For a specific appliance, the level of past electricity consumption is derived from ownership levels, usage patterns and technical change. By establishing the relative importance of these different trends, it is easier to make future projections and to clarify both the limitations of policy intervention and to determine what policy would be most influential. This trend analysis has been undertaken for each of the main appliance groups and is described in the relevant chapters (3-7). It is most developed for the wet appliances, where the historic and projected trends are depicted by use of indices (Figure 4.3). In all cases, a cautious approach has been taken in projecting future levels, erring on the side of little change from the present.

The projections for the business-as-usual (BAU) scenario until 2020 incorporate the effect of policies that have already been defined with a known implementation date. Thus, the energy labels for washing machines and tumble dryers are included, but there is no minimum standard for these wet appliances included in the BAU, as it is still under discussion with the manufacturers. No new UK Government or utility initiatives are included in the BAU as, where they exist, there are no firm descriptions of timing or implementation details. For instance, it is known that the Regional Electricity Companies (RECs) must spend £25m on energy efficiency in domestic appliances by 1998, but the details have not yet been agreed with the Energy Saving Trust.

The other scenario identifies the maximum savings that are known in 1995 to be both technically feasible and economically viable for consumers. This is the economic and technical potential (ETP) scenario. The analysis has been undertaken on the basis of a life-cycle cost: that the additional purchase price for the consumer is paid back at an 8% rate of return by the savings in electricity (and, where relevant, water - see ETP in Glossary). The sophistication of these analyses is greatest for cold and wet appliances (as a result of the DECADE team's involvement in the Group for Efficient Appliances studies), but less so for other equipment. The ETP assumes that by 2000 all new appliances sold have achieved the savings defined as economically and technically available. The debate about confidence levels is addressed in Section 8.5.

Whilst an economic, technical potential exists now, it will be difficult to access in the short-term, from a standing start in 1996. Therefore, the policies identified as appropriate either individually or, more usually, in combination for an appliance group will achieve maximum impact after a few years. The exact time delay and amount of the ETP that is captured for consumers will depend upon the political emphasis given to implementation. The permutations and options are too complex to have been modelled in detail. For simplicity of analysis, therefore, 2000 has been taken as the date by which all appliances on the market will have reached the ETP standard.

### 1.4.4 Comparison between DECADE 1994 and 1995

The major developments in DECADE in 1995 are combined and compared with the initial findings from 1994 in Figure 1.3**.** Other revisions have been incorporated, because of generally better data, and these are explained in the relevant appliance chapters. Even when the changed geographical coverage is taken into account, the net effect is that DECADE has increased electricity consumption in domestic lights and appliances by 7-8% (depending on the year) right back to 1970.

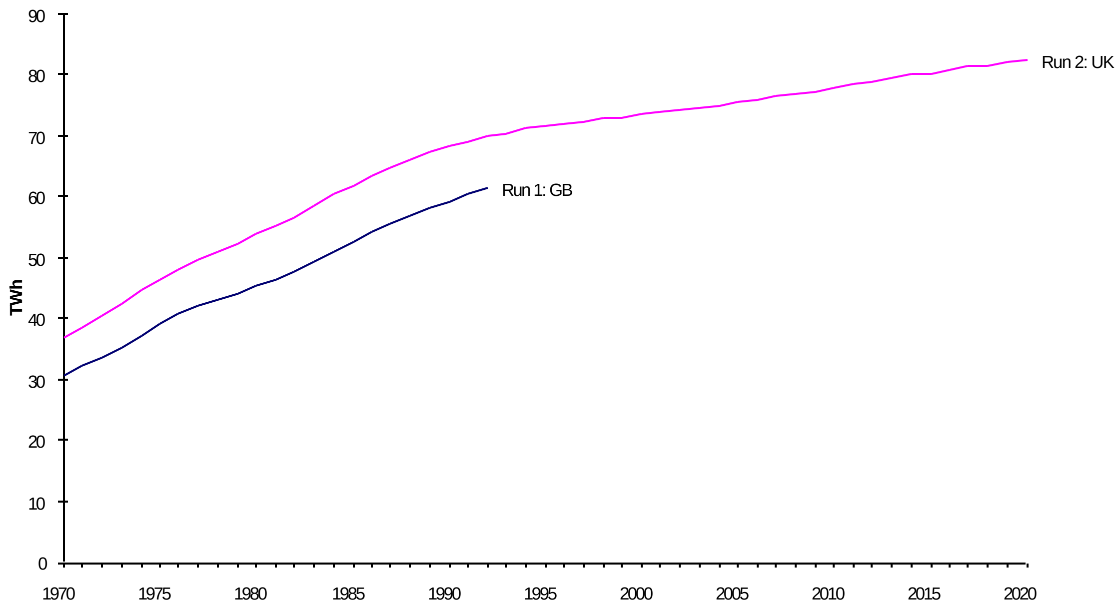


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**Figure 1.3 Electricity consumption in domestic lights and appliances with DECADE 1994 (GB) and DECADE 1995 (UK)**

## 1.5 OTHER BACKGROUND ISSUES

### 1.5.1 Similarities with official Government projections

The Department of Trade and Industry (DTI) has derived the Energy Paper 65 forecasts using technology trends and household numbers as the two main driving, but equalising forces. The DTI population figures do not incorporate the Department of the Environment's most recent revisions (based on the 1991 census reassessment), hence their trends are lower than the DECADE trends. The DTI assumptions are:

- little penetration of new gas-fired appliances, such as tumble dryers;
- electricity prices do not materially affect demand within the range of prices expected;
- the amount of cooking in the home will be affected if incomes rise, because more meals will be eaten out;
- ownership of minor appliances is more dependent on the state of the economy and will grow if real disposable incomes rise;
- ownership of the major appliances - cold and wet, TVs, microwaves and lighting - is near to saturation and will not be influenced by growth in the economy.

The DECADE project incorporates the first two assumptions. There may be a drop in electricity prices as a result of the privatisation of the National Grid and the demise of the Fossil Fuel Levy. The opening up of the domestic electricity market to competition in 1998 may result in a downward pressure on prices. Upward price pressure would occur if a carbon and energy tax is introduced. As a result of the general uncertainty about the likely changes and the effect that they might have, the effect of price changes have not been modelled. For most households, electricity consumption does not change if the price changes: demand is inelastic. The exceptions are low-income families, who reduce consumption after a price rise and incur greater hardship. Even where a consumer is responsive to electricity prices, there are no figures available to link this reaction with specific end-uses, such as lighting or cooking. These economic inputs are unlikely to disturb the findings presented here.

The next two DTI assumptions are deemed to be the least significance and are not factors that influence demand in the DECADE model. The final assumption is treated differently in DECADE: regardless of the state of the economy, the majority of appliance groups will be owned more extensively. The reasons for this are discussed in the relevant chapters and a summary of the projected ownership trends given in Figure 8.3. The net effect, for electricity consumption, of the trends assumed by DECADE, and the difference between these and the DTI projections, are discussed in Chapter 11.

### 1.5.2 Data sources

The team has used a wide variety of data sources. Apart from those publicly available, collaboration with our colleagues throughout Europe has contributed data from their archives and further enlightenment has been obtained from the team's participation in various international conferences. Commercial data on the structure of the market and on appliance performance under test conditions have been purchased. Finally, the detail on actual consumption, monitored in the home, has come from the Electricity Association and Lothian and Edinburgh Environmental Partnership (LEEP). The LEEP data has been a particularly rich source as the research is ongoing and the staff at LEEP and on DECADE collaborate closely. Other information has been obtained from masters and doctoral theses in university departments, as varied as engineering and domestic science. The process of data acquisition is never-ending and more data are always useful. However, the present findings represent the best estimate that can be made in 1995 and are an improvement on past judgements, including our own. The revisions presented here have been achieved through both the availability of more detail and through better modelling.

## 1.6 STRUCTURE OF REPORT

Each section of this report has been written as a collaborative effort, with contributions and comments from all members of the team. (DECADE team members and their qualifications, together with a list of consultants, is given in Appendix E.) However, each section describes the contribution of one person in particular, the lead author.

Chapter 2, Policy Initiatives, describes the individual policy options available and identifies some of the criteria for selection for specific appliances. The next five chapters (3-7) deal with each of the main appliance groups, respectively all aspects of the cold, wet, brown appliances, cooking and lighting, in order of confidence in modelling results. Chapter 8 brings these main groups together with the remaining minor appliances to give the total findings.

One of the unique contributions of the DECADE energy model comes from the emphasis on behavioural issues. This is unusual both in Europe and North America. The reasons for this focus and the data required, and already obtained, are discussed in Chapter 9. All of these discussions on individual appliances and on consumer actions are helping in the development of PRIME, the new model that is being developed, Chapter 10, which describes the way that policy modelling is being developed. Chapter 11 draws the policy implications and conclusions of this study together.

The appendices provide details on the mathematical methodology, a glossary, appliance categories, the definition of market transformation and staff profiles. The detailed data and assumptions are not presented in this report, but the DECADE team will endeavour to answer specific queries.

## 1.7 CONCLUSIONS

Domestic lights and appliances are major consumers of electricity and represent 25% of all electricity use in the UK in 1994. This is more than the combined electricity consumption of the commercial, services, agriculture and transport sectors.

This level of consumption is greater than previously estimated and, even, than assessed by the DECADE team one year ago. The upward revision has occurred because of increased population forecasts after the 1991 census, improved accuracy from better data and more sophisticated analysis.

Domestic equipment is a focus of European and UK policy on energy efficiency and has already resulted in energy labels on refrigerators and freezers. More interventionist approaches, such as minimum standards of efficiency, are being considered. In the UK, new policy initiatives are coming from the Energy Saving Trust, but the total impact has, so far, been limited.

The DECADE project is focusing on this important area of electricity consumption and providing a better understanding of the factors that influence demand. These include the effects of household formation, technological change, lifestyles and usage behaviour. The DECADE approach is to look at the impacts of these on:

- decisions to purchase appliances;
- the range of models available to the consumer and the choice from within this range;
- usage patterns and trends; and
- responsiveness of both consumers and the supply chain to policies, for instance educational energy efficiency labels or minimum efficiency standards.

Although, the quality of the data and the gaps in knowledge on usage were greater than anticipated, there is now a methodology for getting all data on UK domestic electric appliances into one common format. These trends are projected forward to 2020, to give a framework for discussions on possible scenarios. The team can now inform and provide support for policies.

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## CHAPTER 2: POLICY INITIATIVES

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**MARK HINNELLS**

### 2.1 INTRODUCTION

This chapter first defines policy initiatives which may be used to influence the consumption of electricity in domestic appliances, either by altering the characteristics of the market such that more efficient appliances are introduced into the stock or by influencing the way people use the appliances they own. Market transformation could be described as moving the market from a point where energy efficient appliances have a low or very low market penetration, to the point where efficient appliances have a very high or complete penetration, using a combination of product differentiation, incentives and regulation (see Appendix D). A brief review of evidence on the effects of implementing each policy is given, and a variety of factors discussed which would be important in drawing up policy scenarios.

The initiatives outlined here are restricted to those which are both receiving attention in Europe and which can be modelled using the data and methods available to DECADE. Policy issues which are not appliance specific are not addressed here, and these include:

- how to fund incentive programmes, for instance from an Energy Efficiency Levy or alternative utility regulatory structures such as Integrated Resource Planning;
- the effects of increased or decreased electricity prices, whether from real time energy pricing, actions of the regulator, or the effects of a carbon tax or other levy.

Table 2.1 lists the major appliances analysed in this report, and summarises policy initiatives implemented to date, world-wide, and grouped broadly under information, incentives and regulation. Whilst the results of such programmes are unlikely to be directly transferable to the UK or EU, they do provide valuable insights into the possible effectiveness of a range of initiatives.

**Table 2.1 Examples of policy implementation by appliance group world-wide**

| | INFORMATION | | INCENTIVES | | REGULATION | |
|---|---|---|---|---|---|---|
| **Appliance** | **Information and advice** | **Labels** | **Rebate or subsidy** | **Procurement** | **Voluntary agreement** | **Efficiency standard** |
| Refrigerator | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Freezer | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Fridge-freezer | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Washing machine | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Dishwasher | | ✓ | ✓ | | ✓ | ✓ |
| Tumble dryer | | ✓ | ✓(gas) | ✓ | ✓ | ✓ |
| Lighting | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Oven | | ✓ | | | ✓ | ✓ |
| Hob | | | | | | |
| Microwave | | | | | | |
| Kettle | | | | | | |
| Televisions | | | | ✓ | ✓ | |
| Videos | | | | | ✓ | |

Note: a summary of initiatives implemented or close to implementation in the EU is given in Table 1.2.

The policy framework for each approach -information, incentives and regulation- is very different. Information and advice require little legislation, and can be inexpensive. Incentive schemes require substantial funding at the national level. Where goods such as appliances are traded internationally, mandatory energy labels, voluntary agreements and minimum efficiency standards need to be negotiated at the level of the single market if they are not to be a barrier to trade, and thus, the EU Commission has taken the lead in developing minimum standards.
The effects of information on purchase, and especially on use, are uncertain and may be short lived. The effects of incentives may be uncertain, as well as temporally and geographically limited. Regulation is the least uncertain option, affects all appliance sales after introduction (ie is not temporally limited), and is geographically wide in scope, being introduced at the level of the single market. Regulation is very cheap to government and to consumers.

## 2.2 INFORMATION AND ADVICE

### 2.2.1 General information campaigns

It is likely that there will always be a role for general information campaigns initiated by central government, since these provide the necessary climate of public interest for the other policy interventions described here to be acceptable and effective. One of the main elements of UK Government energy efficiency policy has been information campaigns, including “Save it!”, “Helping the Earth Begins at Home” and now “Wasting energy costs the earth”. However, the direct impact of such schemes on energy use is likely to be small and is difficult to estimate.

In Norway, research show that 70% of people remembered energy efficiency campaign, 60% remembered the different products which were focused on, and 5% took the initiative to obtain further information (Toft 1992). An inquiry is no guarantee of action (or action may have taken place as a result of information but without a follow-up inquiry) it seems unlikely that information alone would trigger a change that would not have happened anyway. Given that the savings are difficult to quantify, cost effectiveness is hard to prove.

Many of the early US information programmes had little direct impact on energy consumption because they ‘overlooked the importance of identifying consumer needs and relating information to the consumer’s decision-making process’ (Clinton *et al* 1986). Such information must present the necessary actions, the personal benefits, and a reason to act now. General information campaigns can be made more household-specific and influence both purchase and use.

### 2.2.2 Targetted energy advice

While information is generally available, advice is usually asked for by consumers, from an energy provider, advice centre or retailer. Advice should be independent, credible, concise and simple, in-home or at the point of purchase, and household-specific; it should directly increase people’s knowledge of energy conservation, and include feedback about the effect of a specific action.

The ‘EcoFeedback’ scheme has been running in the Netherlands for over a decade. The scheme involves householders recording energy meter readings each week, and comparing consumption with that of the same period last year. The local newspapers contain target values (compared to the previous year's consumption and including a weather correction). 25% of all households are participating. Of these, 60% have reduced their energy consumption by 10% (Walker 1993).

In Helsinki householders have been provided with electricity bills which state their actual use (rather than an averaged estimate) and were accompanied by a separate letter about how their electricity use compared from year to year together with tips on energy saving (Arvola *et al* 1994). Bills of actual use led to reductions in consumption compared to a control group, and feedback increased the difference between the control and the experimental group. Also, the impact of feedback did not appear to be reducing over time, so the effect would seem to be sustainable. Finnish households receive bills 10 times a year, and therefore the frequency of the information they received is much higher than has been the case in the UK. Customer response to the initiative was positive since the perceived level of service increased.
While in Finland the energy utilities are seen as credible sources of information about energy saving, this situation may not be transferable to the UK: Meyel (1987) noted a high degree of scepticism towards energy efficiency advice provided by the electricity and gas utilities. In a recent Consumers' Association survey (CA 1994), the service offered by British Gas and by the Regional Electricity Companies varied considerably in quality and comprehensiveness. The Consumers' Association found the Local Energy Advice Centres more helpful, though their focus has to date been very much towards heating rather than appliances.

A problem both of information and of advice is that they are often absent at times when key decisions are being made, like buying an appliance: energy labels are information at the point of sale aimed at influencing appliance choice. Retailers may use the information in the label to provide advice.

### 2.2.3 Energy labels

Labels include absolute energy consumption under test conditions, information about size or capacity (eg litres of storage space or kilogramme of clothes washed) and sometimes performance (ability to clean clothes). Appliances are also graded on a scale of A-G, according to how efficient they are (energy consumption per unit of volume) compared to other models (the washing machine energy label is illustrated in Chapter 4, figure 4.5). In the EU it has been mandatory to apply labels to cold appliances since January 1st 1995. Washing machines and tumble dryers must be labelled from 1st April 1996. Labels for dishwashers, light bulbs and water storage heaters will soon follow.

At the beginning of a decision to purchase, people tend to scan the range of models (eg of refrigerators) on one or two dimensions (eg price and size). Only when a number of acceptable alternatives is found, do other factors such as energy consumption or the shape of the storage trays in the door, become influential. Even early on in a search, if an appliance is too expensive, people will tend not to look for other factors such as energy efficiency, which might compensate for a high price. The aim of the energy label is to make energy consumption as salient as possible. It therefore has to have several essential characteristics: ease of understanding, relevance to the purchasing decision, and ease of recall. Two products may not actually be on display in the same store for direct comparison. The design of the label is therefore very important (de Loor *et al*. 1991).

The US introduced the Energy guide label in 1980 (McMahon 1991) and since then schemes have been adopted in Canada and Australia (Pears 1988; Grzesik 1992). The first EU directive on energy labelling for appliances was passed in 1979 (79/530/EC), but it was not mandatory and implementation was limited. Several countries have had voluntary labelling schemes on various appliances, including refrigerators, freezers, fridge-freezers and ovens. Directive No 75/92 provides a framework for the mandatory introduction of energy labels for a variety of domestic appliances in the EU.

Energy labels have an effect on consumer choice, and on the models that retailers choose to offer, or the models that manufacturers produce. If retailers expect demand for less efficient appliances to fall, they may cease to stock such models. Manufacturers may increase production of more efficient models either as a response to increased retailer demand or because they perceive a marketing opportunity for more efficient products. Manufacturers or retailers may also choose to increase the price of efficient appliances if they expect the consumer to see high efficiency as adding value to the product.

In the US, research could not establish a causal relationship between the introduction of energy labels and a reduction in energy use (McMahon 1991). The energy saved in domestic appliances during the period studied was assigned to other causes, particularly to normal, market-driven, technical improvements that would have happened anyway. However, MacMahon noted that energy labels are an essential basis for other policy initiatives (such as cash rebates) which have been much more effective.

In Australia, labels have been applied to the cold and wet appliances. The effect on the efficiency of appliances sold differs between appliances, ranging from an additional 1-2% pa improvement over a five year period in cold appliance efficiency, to no discernible effect on the sales-weighted efficiency of washing machines. Annual energy consumption of all new appliances purchased in 1992 in appliance groups which are labelled in Australia would have been 11% higher if the labelling scheme had not existed (Wilkenfeld 1993). The Australian experience also suggested that manufacturers may alter product design so that models just reach the efficiency needed to move to the next higher category on the label, and that the effects of the label last for the duration of one product design cycle, or around 5 years.

Within the EU a pilot project to assess the effectiveness of energy labels for cold appliances was carried out in Denmark. Initial results from the programme suggested some shift to purchases of more efficient appliances with reductions in sales of D and E appliances and increases in B and C appliances (Jeremiassen 1994). However, the scheme coincided with a pilot rebate scheme and heavy advertising, so results cannot be transferred to situations where such additional measures are not in place.

In a similar pilot scheme by Scottish Hydro-electric there was a reduction in twelve months in the number of F and G category models stocked, in favour of more C and D rated models. There appears to have been little change in the number of very efficient models offered. The net effect was a 19% improvement in efficiency of cold appliances stocked, bringing average efficiency up to the existing EU average (see cold appliances, Chapter 3).

Manufacturers have also introduced design improvements for the cold appliances coincident with the introduction of labelling. Thomson (a French manufacturer) has reduced the number of cold appliances offered in categories E, F and G, and increased the product range in category D, but there are no new models in the top three categories. Two German manufacturers, Bosch and AEG, have reacted differently. The number of appliances offered which fell into the bottom four categories was already low, but has been reduced, and while neither manufacturer had appliances in category A in 1994, both AEG and Bosch now have 70% + of their models in label categories A and B. The net improvement in a single year has been 27% by AEG, 18% by Bosch, and 4% by Thomson.

The effect of labelling seems to have been variable. In the US and Canada, there is little or no evidence of a causal relationship between improvements in energy efficiency and labels. In Australia, improvements seem to have been product specific. The early evidence from EU manufacturers and retailers is of a considerable improvement in the first year of labelling for the cold appliances which may or may not be continued, and which may be exclusive to the cold appliances where the greatest improvements can be made with the least increase in purchase price.

An important factor for consumers is the ability to interpret the information on the labels. The EU label has been seen more as a product information label rather than an energy label, with much additional information which detracts from the data on energy use (de Loor and Zeelenberg 1991). The Adult Literacy and Basic Skills Unit suggest that the design of the EU washing machine energy label will cause comprehension difficulties for significant numbers of people who have difficulties with basic reading and maths, and are unfamiliar with either the terminology used on the label, or the process of converting energy use to cost (Morphy, 1995, *pers. comm.*). DECADE has performed further analysis of the effects of energy labelling of cold appliances on consumer choice, and preliminary results are included in Chapter 9. The ability to interpret labels, and thus their effectiveness will depend on manufacturer advertising, and government or retailer advice accompanying the introduction of labels (Clinton *et al* 1986; Moisander and Kasanen 1993; Slater and Webber 1994; Casey-McCabe and Harris 1995).

In summary, energy labels affect consumer choice directly at the point of sale as well as indirectly via the range of appliances offered for sale. To date there is little empirical evidence to support conclusions about effectiveness, which varies between appliances, with the design of the labelling scheme, and with the additional information supplied to consumers by retail staff and others. However, energy labelling is an important precursor to other schemes.

### 2.2.4 Other types of label: energy star and eco-label

While energy labels are graded, other types of label can be pass/fail labels, such as the US Energy Star scheme for personal computers and printers, and the EU eco-label.

Energy star is awarded to computers and printers for low power consumption when on but not in use. Some 80% of US computer sales are now energy-star compliant. The effectiveness of the scheme is probably enhanced by the near-zero incremental cost involved in the adoption of the new technology.

Criteria for the eco-label are set on the basis of a life cycle analysis so that the top 10-20% of products in any category qualify. For some product categories, especially appliances, energy in use is among the two most important factors over the life cycle. However, in order to use the label, manufacturers first have to apply and pay a licence fee. The scheme was designed on market research evidence in the late 1980s that consumers were willing to pay a premium for products with reduced environmental impact. This premiss has not been proven from observed purchasing behaviour, especially in years of recession. The scheme could be seen as a tax on efficiency or reduced environmental impact (Hinnells and Potter 1994). As of September 1995, only one product has been awarded the eco-label, a Hoover New Wave washing machine. To date, the scheme has incurred considerable start-up costs, with no proven environmental savings.

The House of Commons Environment Select Committee has noted the overlaps in terms of administration between eco-labels and energy labels (HMSO 1993), but more important for the consumer, a potentially confusing situation is emerging. *Most* domestic appliances will have graded energy labels, *some* office equipment might be awarded an energy star, whilst eco-labels may be awarded to some domestic appliances and some office equipment. The difference between an award label and a mandatory graded information label is not always understood. Consumers in Canada (De Hart 1993) and in the US (Harris 1995) see the energy label as product endorsement rather than as information, and may choose an inefficient model on the assumption that because it has a label, it has been approved as energy efficient. It is therefore important to examine not only the administration, but the *raison d'être* and effectiveness of each type of label with a view to rationalising consumer information (Hinnells and Potter 1994).

The effects of information, advice and labelling on their own are uncertain, but can be enhanced by incentives (rebates, grants, loans and technology procurement) and regulatory approaches (voluntary agreements and minimum efficiency standards), and these are now examined.

## 2.3 INCENTIVES

An incentive is an financail inducement to purchase a more efficient appliance than would otherwise be the case. This can take the form of a discount, a full grant or differential tax. In the UK most of the incentives are being coordinated by the Energy Saving Trust as the Regional Electricity Comapanies have £100 million to invest in th more efficient use of energy between 1994 and 1998. One quarter of this is earmarked for appliances, not including lighting. As of September 1995, no appliance programmes had been validated under the Standards of Performance. Incentives can be national or more local.

### 2.3.1 Rebates

A direct cash rebate can reduce the purchase price of the most efficient appliances, or encourage replacement of the oldest (and least efficient) appliances in the stock. To date schemes have been most common for lighting and cold appliances, but schemes have also targetted washing machines, dishwashers, and low flow shower-heads. Rebates may act as an economic incentive, though much of the effect is thought to be the psychological effect of official endorsement (Trines 1994 *pers comm*). Participation rates are not necessarily correlated with the level of the rebate offered, and factors such as the effectiveness of the promotion strategies are important (Mills 1991).

Any rebate scheme needs to be based on some form of identification of the most efficient appliances, for example, those that carry an A or a B of a graded energy label, or carry an energy star or eco-label. In the case of large appliances, many schemes require take back of the old appliance for recycling to ensure that it has left the stock, which is important to guarantee energy savings.

In a scheme to promote Compact Fluorescent Lamps (CFLs) in the US, rebates of $4.70 were offered for bulbs whose usual price averaged $9. From the expected 80% reduction in consumption, premature withdrawal of CFLs from service due to unsatisfactory performance reduced savings by 16%, while 20% of the efficiency improvement was taken as an increase in light output. The net saving was just over 50% (Horowitz and Spada 1992).

In the UK, the Energy Saving Trust (EST) has run several schemes to increase the purchase and use of CFLs by lowering the sale price of the bulbs since the first pilot scheme in 1993. The subsidy has been direct to manufacturers at a rate of £1 per bulb, and by the time this reaches the consumer, the price of the bulb has been reduced by around £5. In the first pilot, the subsidy was offered on sales for a period of eight weeks, and the target for the scheme was to increase sales from an expected 150,000 to 600,000. During the period of the scheme sales of bulbs reached 740,000 (Heywood and Rowbury 1995). The scheme was repeated in 1994. An additional 950,000 lamps were sold in three months. In addition to the increase in sales during the promotional period, there has also been a noted residual effect in a period after the end of the scheme. Market research, carried out to assess the impact of this latter scheme indicated that awareness of CFLs had increased (from 58 to 72% of all households). Also, an estimated 500,000 households bought CFLs for the first time, increasing the number of households using the lamps from 11% to 13%. Of those who bought a lamp during the promotion, over half would not have bought the lamps if they had not been on offer. Thus the free-ridership level is somewhere in the region of 50%. Most of the purchasers of CFLs came from upper income households despite the significant price reduction, suggesting that even with the subsidy, initial purchase price may still be a barrier to uptake for many consumers.

A German electricity utility (RWE) offered a 100DM (£25-30) rebate to customers who purchased energy efficient refrigerators, freezers, dishwashers or washing machines between 1992 and 1995 (Thomas 1995). The rebate offered was and applied to the most efficient 50% of appliances on the market. The proportion of free-riders is thought to be high, ranging from 57% to 72% of all purchasers, because such a large proportion of appliances qualified for the rebate. The programme was cost effective from both the customer and societal perspective, but not from the utility perspective. The total saving was estimated to be 453 GWh.

In the Netherlands a pilot and later a national scheme for cold appliances gave a rebate of 20 ECU (£15) to consumers buying an appliance in A or B of the energy label. The model had to be CFC-free and the old appliance had to be returned for recycling (Niewenhuyse 1994). Of those consumers who claimed a rebate, around half of them would have purchased one of the energy-efficient appliances in any case, whilst the other half had not decided which appliance to buy prior to entering the store: thus the scheme may have doubled the number of purchases in the A and B bands, as was its aim. A similar campaign in Denmark provided consumers with rebates for the purchase of new freezers in category A or B of the energy label, if their existing freezer was more than ten years old (Larsen 1993).

Rebates have been common in US utility companies for several years, alongside other appliance programmes such as minimum standards. For models saving 10-15% more than the Federal minimum efficiency standard Pacific Gas & Electric (PG&E) offered a $50 rebate. For models saving over 15% more than the standard PG&E offered a $100 rebate (Proctor 1993).

The lessons from these examples are important for scheme design: the rebate has a psychological rather than an economic impact, and the size of the rebate is less important than additional information, together with advice from the retailer. The qualification levels are crucial in maximising savings from schemes, and in the past, qualification levels have been set too low and encouraged a high level of free-riders. Graded rebates encourage savings beyond the levels of efficiency standards or the effects of other initiatives. Savings can be increased by targetting replacement of the oldest appliances in the stock and ensuring replacement by recycling the old appliance. Actual savings are never as high as estimates suggest because some of the improvement in efficiency is taken as increased service, and because some consumers revert to previous technologies due to dissatisfaction with the performance of the replacement. This is especially true for lighting (see Chapter 7).

### 2.3.2 Grants

While middle income groups may need a relatively small incentive to change from an average new appliance to the best new, low-income groups may need a 100% rebate -a grant- in order to trigger a replacement, for example, of a low energy light bulb. Qualification may depend on the customer being in receipt of one of a number of means-tested benefits.

In a scheme in the US in the early 1990s, almost 200,000 CFLs were directly installed in low-income households, at no cost (Granda 1992). The Energy Saving Trust provided electronic CFLs, free of charge, to 200,000 households receiving energy advice through the Home Energy Efficiency Scheme and on benefit. 9% of these households have since gone on to purchase another CFL, suggesting that ‘the free CFL has stimulated demand for further CFLs to a significant level among social groups who are otherwise slow to adopt them’ (Heywood and Rowbury 1995).

### 2.3.3 Finance schemes

Credit schemes can be set up to provide low-interest loans linked to the purchase of an energy-efficient appliance, the repayments on which can be funded from the resultant energy savings. Several groups (including LEEP) are currently investigating such schemes, while some European utilities allow the consumer to spread payment for CFLs and efficient appliances over several months, via the electricity billing system (Mills 1991). Finance schemes may have a similar combined psychological and economic effect to rebates, but can be provided at a lower cost to government or a utility.

Other schemes may be run by retailers, and focus around rental/purchase (eg, Radio Rentals, undated) which could offer more attractive payment packages for the more efficient models from their ranges (though many such schemes command very high rates of interest, of the order of 26% APR).

### 2.3.4 Differential rates of taxation on appliance purchase

Rebates could, in effect, be introduced via the tax system. Differential rates of value added or purchase tax were proposed as early as 1952 in the UK. The Committee on National Policy for the Use of Fuel and Power Resources recommended to the Secretary of State that new minimum standards of performance be determined for solid fuel room heating appliances, and that appliances which do not conform with such standards should be subject to 100% purchase tax (HMSO 1952 para. 138).

The concept of variable rate purchase tax has been applied to motor vehicles. Ontario has developed a ‘feebate’ (combined fee and rebate) scheme whereby cars with poor fuel efficiency attract a sales surcharge which diminishes as fuel economy improves, with the most efficient receiving a rebate. In the UK differential tax rates for leaded and unleaded fuel provoked a huge investment in converting cars to unleaded fuel, in return for a longer term cost saving and a perceived environmental benefit.

Currently VAT is 17.5% on energy saving goods and 8% on domestic energy. A Bill drafted by the Association for the Conservation of Energy would remove this market distortion and cut VAT on energy saving goods from 17.5 % to 8%. The Bill could include appliances where a labelling scheme exists to differentiate efficiency. If appliances in category A and B of an energy label qualified, savings would be at a cost equivalent to savings under the electricity regulators' Standards of Performance. Amongst the benefits, the scheme would not be as short-lived as rebates, and the legislation would receive a great deal of public attention; manufacturers would have a clear price incentive, and a clear efficiency target. Thus within a few years the qualifying levels may become a *de facto* efficiency standard. The scheme would stimulate the development of labelling schemes for other appliances.

### 2.3.5 Procurement programmes

Rebates, grants, loans, finance schemes and differential rates of taxation may all increase the market share of the best technologies available. Government is itself a large purchaser and could enhance markets for energy efficient and environmentally acceptable products by altering their purchasing policy to ensure that such products are chosen wherever possible (McKane *et al* 1995). Government could also provide co-ordination at the national level to avoid duplication of information search costs, and develop incentives such as national awards for energy management.

However, technology procurement can bring new technologies to market. Government has traditionally supported technical development via direct financial support for manufacturers or research institutions. However, such innovation may never reach the market. Technology procurement creates an initial guaranteed market for a new or improved technology and therefore reduce the risks associated with new product development. Amongst the most attractive options for technology procurement are those appliances which show the biggest gap between current efficiency levels and the technical potential.

Technology procurement has several stages. A group of bulk purchasers (eg housing associations or hotels) is assembled and a technical and economic specification is developed. The specification is put out to tender, and manufacturers who are interested bid to win the contract. In addition to the purchaser group buying the agreed amount, the new product can often be integrated into best practice programmes and it's profile raised. In this way, a strong market for the new product can be opened up, and innovation introduced to market sooner than would otherwise have occurred.

In Sweden, NUTEK have developed procurement programmes for washing machines, refrigerators, efficient computer monitors, windows, and for electric vehicles (NUTEK 1994). A scheme to improve the efficiency of household refrigerators was won by Electrolux for a unit with an electricity consumption 30% less than the most energy efficient on the market at that time. The procurement programme is supported by information dissemination to bring the new products to the attention of a wider range of purchasers, thereby provoking other manufacturers to introduce models with similar efficiency. Over a period of just one year, average electricity use by the market's ten best fridge-freezers fell by 20%. Prices have dropped considerably since the completion of the procurement programme (NUTEK 1993). Since the scheme in 1991, the market share of appliances with an energy consumption of 1.1 kWh/litre or better have gone from 0.8% to 22.2% market share (Johnson and Bowie 1995). However, proving a causal relationship between the procurement and the improvement on the market is quite difficult, although anecdotal evidence from manufacturers suggests that the scheme was an important factor.

The US Super-efficient refrigerator programme (SERP, or the Golden Carrot Programme), was launched in the summer of 1992, and with a very much larger prize (equal to around £20 million, rather than the £60,000 offered by NUTEK). SERP brings utilities together to provide incentives to a single manufacturer to be chosen through competitive bidding to build and deliver up to 250,000 refrigerators that are 25-50% more efficient than 1993 Federal appliance efficiency standards (Frantz 1993). The prize was awarded on a combination of factors (time of delivery, number of units, and efficiency) which together totalled the greatest number of kWh avoided for the utilities. How much each utility was prepared to invest depended on its estimated avoided costs and energy saving. The incentive payments were of the order of $100-150 per unit (£66-100). Annual savings could be 200-400 kWh beyond the 1993 refrigerator efficiency standards.

There will be an aspect of procurement in future EST rebates for CFLs: manufacturers have been given notice that subsidies will be slanted towards CFLs which are cheaper, smaller in physical size, and greater in light output, and thus are provided with an incentive to develop such bulbs.

Procurement activities are now being co-ordinated under the International Energy Agency programme (Demand-Side Management Annex III). Of particular interest at the moment are wet appliances and standby consumption in televisions and videos.

Primary candidates for future technology procurement programmes include vacuum panel insulation for cold appliances, and the bringing together of a variety of design options to improve the efficiency of ovens. The need to demonstrate the viability of vacuum panel insulation is discussed in more detail in chapters on the cold and cooking appliances.

## 2.4 REGULATORY MECHANISMS

Regulatory schemes aim to change the models on offer to consumers. In the short term, voluntary and mandatory schemes may be seen as similar: in order to gain a 10% efficiency improvement in the average new appliance bought, there is little difference in practice between a voluntary agreement and a mandatory standard. However, negotiation of short term voluntary agreements may delay and distract from the establishment of long term efficiency targets, which may ultimately require framework legislation at the EU level, with an agreed timetable of improvements across a range of appliances, aiming at minimum life cycle cost.

### 2.4.1 Voluntary agreements

While incentive schemes increase market share of the best technologies, and technology procurement brings new technologies to market, there are other initiatives which might underpin technical improvements, and require that a high percentage of products meet certain efficiency standards by a certain date. These may be agreed voluntarily with industry, or if necessary mandatory regulation may be introduced.

Voluntary schemes have been employed in Germany and Switzerland. In January 1980, the then West German Government and appliance manufacturers concluded a voluntary agreement to improve the sales weighted efficiency of appliances by 20% in five years, monitored by the publication of a report (Monitorische Berichte). While this target was met and even exceeded, the agreement was not renewed. It was felt by the manufacturers that most of the potential for improvement had been accessed without conceding market share to other (non-German) manufacturers, and for cold appliances attention was focussed more on CFC-replacements (Hass 1992).

Based on legislation in 1992, the Swiss Government has set a series of target values for a range of electrical appliances including cold, wet, audio-visual appliances and office equipment. The programme stipulates that 95% of sales have to achieve the target values, and the programme is supported by the clear intent to introduce minimum efficiency standards if the targets are not met. The threat is not implied, it is explicit. Target values announced in June 1994 are to be reached by the end of 1997 (SFOE 1993). However, there is little evidence to date as to whether targets will be complied with.

The EU Commission has been of the view that a satisfactory voluntary agreement would have to include three main elements (CEC 1995):

- commitments by manufacturers accounting for most of the appliances sold on the market (say 80% to 90% at least);
- quantified commitments to significant improvements in the energy efficiencies of the appliances they produce over a reasonable timescale and;
- an effective and independent monitoring scheme of improvements in energy efficiency.

The Commission was not convinced that voluntary agreements for cold appliances met these three objectives, and decided to press ahead with mandatory standards. However, standards for other appliances seem uncertain at present. The Commission apparently retains a preference for voluntary agreements, and is negotiating therefore with manufacturers of washing machines, televisions and videos. If a voluntary agreement is not concluded, mandatory standards remain a political option, either at the national level if one government feels especially strongly, or at the EU level.

### 2.4.2 Mandatory minimum efficiency standards

Mandatory standards can either require a maximum allowable energy use by an appliance in normal use, a minimum level of efficiency, or can specify a characteristic to be included in appliance design. Mandatory standards require 100% compliance with clear penalties for infringement. Mandatory standards are most appropriate where there is a range of efficiencies on the market, where designs are easily altered and where technical change is slow. Standards may not be appropriate where it is difficult to define efficiency under reproducible conditions, where the appropriate technology has a very low market penetration and costs and benefits are difficult to determine, or where technology is changing rapidly (eg personal computers).

Several countries already have, or are in the process of implementing, mandatory standards, including the USA, Canada, and Australia. The first mandatory standards were issued in the US in 1987 for refrigeration appliances, to become mandatory in 1990, and required a 10% improvement in average efficiency of new appliances. A second round of standards published in 1989 required an additional 30% improvement over the 1990 standards, and became active on January 1 1993. For all classes of cold appliance only 7 models out of the 2,114 models sold in the US in 1989 meet the 1993 standards, thus virtually the entire market needed to be redesigned. A new round of standards for refrigeration appliances were agreed with manufacturers in early 1995 to be implemented in 1998, based largely on the winner of the SERP (Super-Efficient Refrigerator Programme, Geller 1995). Of particular importance in the US has been the effectiveness of a regular timetable of widening standards to other appliance groups, and progressive tightening of standards.

In the US, annual energy savings exceed the increased purchase price to consumers within four years. For the total appliance standards enacted by 1992, the US will save (over the period 1990 - 2015) $46 billion net, energy bills being $78 billion lower, with $32 billion added to the value of appliance sales. Utility costs also diminish, from a saving in 2015 equivalent to 21 power stations, and a total saving of 393 million tons of $CO_2$ (McMahon 1992).

In the EU, Denmark and the Netherlands have framework legislation in place at the national level to introduce standards. The Dutch Government notified the Commission of its intention to introduce efficiency standards for cold appliances in 1992, and the Danish Government notified the Commission of its intention to introduce standards for the wet appliances in 1994.

Under EU law, a single country cannot bring forward national proposals which might be considered a restriction on trade, for a period of one year, until the Commission has had the chance to bring forward its own proposals. Accordingly, the Commission asked the Group for Efficient Appliances to examine the technical basis for minimum efficiency standards for the EU (Greenwood 1992). In addition, the Scandinavian countries under the Nordnorm Commission had been discussing standards, and held a meeting in Stockholm in May 1991 to discuss options, while a third study proposed standards for Austria (Sakulin and Dell 1991). Both the Nordnorm Commission and Austria decided to delay their own standards, and to wait for EU standards.

A draft directive is currently before the EU Parliament and should be agreed before the end of 1995. It would require a 10% improvement of the average new appliance. These proposals may result in little additional improvement over and above what may result from the introduction of labelling, and are well short of the minimum life cycle cost level found by GEA. To date, only the US standards which came into force for cold appliances (1993) and wet appliances (1994) are based on technical and economic assessment of minimum life cycle cost.

However, there is some disagreement amongst Member States as to the desirability of standards, the speed with which they should be introduced, and the extent to which manufacturers should be asked to redesign products. For example, the German and Italian Governments oppose regulation, whereas some governments (particularly Denmark, the Netherlands, and Austria) feel that progress at the EU level is too slow.

In summary, minimum efficiency standards require 100% market penetration for efficient products by a certain date. Standards are in place or under development in the US, Canada, Australia, and the EU. Standards imply higher equipment prices, but lower energy costs, and have a payback usually less than 5 years.

## 2.5 LINKING POLICY INITIATIVES WITH APPLIANCE GROUPS

Theoretically any of the policy interventions described above could be targetted at any appliance group. Applying this theoretical perspective to a product category requires analysis such as: What is the scope for reduction in electricity use, both in absolute terms, and relative to other appliance groups? Can efficiency be easily measured? Is there a range of efficiencies on the present market? Can products be differentiated by labels? Is there a new technology on the market but which has a high purchase price, high marketing costs, and does not yet benefit from economies of scale? (eg CFLs and induction hobs). Is there a large technical potential for improvement? Is implementation politically feasible given rates of technical change, consumer acceptance, and manufacturer acceptance?

Each of these points is discussed in turn. The balance in terms of innovation and diffusion will be different for each product category. The appropriate combination of initiatives to achieve market transformation is developed further in each appliance chapter. Additional issues are not discussed here but might include the interaction between say, social policy and appliance energy use, or the possible contribution to load management of decreasing consumption in a particular appliance.

### 2.5.1 Policy selection for new appliances

A reproducible measure of consumption and efficiency (and increasingly performance) is a pre-requisite for policy intervention to improve new appliances. For many appliances test protocols already exist (eg the cold and wet appliances). However, for some appliances where this is not the case, there may be no reason why a protocol could not be developed (eg standby consumption of TVs and videos). A test method exists for ovens but needs updating. Test methods are a priority for hobs and other cooking appliances. A key obstacle in the EU at present is that manufacturers have almost complete ownership of development of test protocols. In the US, the Department of Energy can instruct National Institute for Standards and Tests (NIST) to revise the test procedure -quickly- to make it more appropriate for policy.

Manufacturers have to be well attuned to consumer preferences. If consumers do not consider energy, environment or running costs to be important then manufacturers will pay little attention. If, conversely, these issues are seen as a priority, they will become a priority in product development. Thus, manufacturers and retailers both follow and may to some extent guide, consumer choice - if consumer choice can be given a voice. A label may access savings where there is a large range of efficiencies on the current market (Table 2.2 Column 1). This will be most effective where consumer awareness of energy is already high (Column 2), otherwise the label needs to be supported by an effective information campaign to have an impact. This would allow consumers to exercise choice.

Where consumers do not give a priority to energy efficiency at the point of purchase, then a financial incentive in addition to a label may be effective in focussing consumers, retailers and manufacturers attention on efficiency. Procurement is appropriate when the technical potential is much greater than anything on the current market (Column 4).

Voluntary agreements may be more appropriate than regulation where technology is not stable but changing fast (Column 3), for example standby consumption in brown goods. Standards are more appropriate where technology is stable (eg the cold appliances). A first round of standards can move the market towards the best currently available (Column 1), and a second round achieve the economically justified technical potential (Column 4).

**Table 2.2 Indicators for policy selection for new appliances**

| Appliance | Large efficiency spread on the market?[1] | Consumer awareness of energy[2] | Stable technology?[3] | Large ETP?[4] |
|---|---|---|---|---|
| Refrigerator | very large | no | medium | very large |
| Freezer | very large | no | medium | very large |
| Fridge-freezer | very large | no | medium | very large |
| Washing machine | large | no | stable | large |
| Dishwasher | large | no | stable | large |
| Tumble dryer | large | yes | stable | small |
| Lighting | very large | yes | not stable | very large |
| Oven | large | no | stable | large |

| | | | | |
|---|---|---|---|---|
| Hob | no | no | medium | large |
| Microwave | no/yes* | no | stable | small/large* |
| Kettle | no | no | stable | large |
| Televisions | yes/yes* | no | not stable | unknown/large* |
| Videos | no/yes* | no | not stable | small/large* |

Notes: *Where two answers are given above (eg no/yes) the first applies to the use mode, and the second to standby.
1. A large efficiency spread on the market is where the average efficiency of the top decile of the market is at least 25% greater than that of the bottom decile.
2. Consumer awareness of the energy use of the appliance will be judged to be high if energy efficiency is ranked as one of the top three characteristics determining appliance choice. Clearly this may change over time.
3. An unstable technology includes rapid but incremental changes in technology (the short product life for videos), or where fundamental changes to technology could occur (eg introduction of vacuum panels for refrigeration).
4. A large ETP is where the economically justified technical potential (at today's fuel prices and using proven technology) is at least 25% more efficient than the market average.

### 2.5.2 Policy selection for alterations in appliance use

This is important since behaviour affects the whole stock of appliances in homes, not just those bought new. Where variation in usage is great and savings from improved use are substantial, advice may be as important as changing the technology of machines sold. For example, for hobs there is a wide variation in usage from pan selection, use of a lid and other factors (Table 2.3 Column 1). There is scope therefore to reduce energy use (Column 2). Consumer understanding of the savings from behaviour is not high, therefore advice may be effective (Column 3). Advice on use is not likely to have much effect on refrigerator consumption.

**Table 2.3 Efficiency opportunities in appliance use patterns**

| Appliance | Wide variation in use pattern?[1] | Scope to improve efficiency of use?[2] | Consumer understanding high?[3] |
|---|---|---|---|
| Refrigerator | no | no | no |
| Freezer | no | no | no |
| Fridge-freezer | no | no | no |
| Washing machine | yes | yes | no |
| Dishwasher | yes | yes | no |
| Tumble dryer | yes | yes | yes |
| Lighting | yes | yes | yes |
| Oven | yes | yes | no |
| Hob | yes | yes | no |
| Microwave | yes | yes | no |
| Kettle | yes | yes | no |
| Televisions | yes in standby | yes in standby | no in standby |
| Videos | yes in standby | yes in standby | no in standby |

Notes:
1. A wide variation in use pattern means some households use at least 25% more electricity than others for a given household size and appliance specification.
2. Scope to improve efficiency of use indicates that at least 1/3 of the variation in energy use between households can be attributed to the use of more energy to provide the same service (ie a variation in television electricity use simply because one family watches more hours of programming per week would not indicate scope for improvement, whereas there is scope to reduce the variation caused by leaving on standby overnight).
3. Consumer understanding is high if consumers are already aware of the ways in which their behaviour affects the energy required to provide a given service. Consumer understanding is difficult to define: it may be perceived to be high for lighting, but estimates of lighting consumption in surveys are notoriously inaccurate.

## 2.6 COMBINING POLICY INITIATIVES

Initiatives are complementary. Consumer education is of little use in isolation, but effective in increasing energy savings from labels. Labels segment the market in terms of efficiency, and are a necessary base for rebates. The US refrigerator ‘golden carrot’ programmes are paving the way for a new round of more stringent efficiency standards by stimulating the market to increase the average efficiency of appliances on sale (Geller and Nadel 1994). It is often claimed that minimum standards stifle innovation, becoming a de facto maximum efficiency rather than a minimum efficiency (building standards are a case in point). However, maintaining other incentives such as labels, rebates and procurement avoid this effect and ensure that there is always a clear incentive to improve efficiency.

Market transformation is described as moving the market from a point where energy efficient appliances have a very low market penetration, to the point where efficient appliances have a very high or complete penetration. Within this, different policy initiatives achieve a different part of the transformation (see Appendix D). The direct effects of technology procurement could be to increase market penetration of a new technology to 2% or 5% while the indirect effect may be much greater: as rival manufacturers introduce similar products to market in order to compete, the technology may increase to say 10% penetration. Rebates or tax differentials could increase penetration to say 20-40%. Minimum standards may underpin the transformation and increase penetration of an efficient technology to 100%.

The most beneficial combination of initiatives will depend upon a variety of factors. These include the objectives to be achieved as well as the characteristics of the appliance and its market, as identified above. A lack of co-ordination between policy-makers working on apparently separate elements of market transformation could lead to say, rebates and efficiency standards trying to make the same saving twice. The most appropriate combination of policies could achieve a synergetic effect and produce greater savings than the sum of the individual initiatives.

## 2.7 MODELLING POLICY INTERVENTION

The spectrum of data needs for modelling policy intervention is wide:

- an understanding of underlying rates of improvement in the market is important for all policy options;
- a clear understanding of consumer responses is important for advice, information and incentives but is less important for technology procurement, voluntary agreement and minimum efficiency standards;
- a good understanding of current technology is important for rebates, labels and standards and of future technologies for minimum life cycle cost standards and technology procurement;
- sales-weighted data are needed for an assessment of incentive programmes such as labels, rebates and technology procurement.

In terms of certainty and ease of modelling, advice, information, and labels are not certain, while efficiency standards are by far the most certain.

The effects of combinations of policies (market transformation) are hard to model as they depend upon an understanding of the distribution of efficiency, rather than average efficiency, and the way that this range of models is affected by policy. For instance, if a model is taken off the market, because it is below an agreed standard, it may or may not be replaced by a new, more efficient model. The manufacturer could decide to retain the existing, restricted range. A judgement has to be made for the statistical model on the efficiency of models offered by the manufacturers and how retailers and consumers respond to the new range of appliances. Only then can the savings be estimated. In addition, the new policy intervention is usually announced considerably in advance, so that manufacturers have time to adjust their designs, before the policy commences.

There are other aspects of the detailed design of policies that have a crucial effect on the likely impact. The inclusion of wash performance rankings on the energy label for washing machines is expected to divert consumer attention away from the energy efficiency levels. Therefore, the impact of this energy label is expected to be very different from that of the energy labels on the cold appliances. A further example with labels is that their impact is strongly influenced by the knowledge of the retail staff. Consumers are influenced by the assistants, particularly with rare purchases, such as white goods, that are bought in ‘distress’ because the old appliance has failed. If the retail chain has not trained their staff and discussed the importance of energy efficiency with them, the impact of the label will be much reduced. Unpredictable aspects of the policy as implemented, such as these, mean that even the broad effect can be difficult to determine.

For all these reasons, the effects of individual initiatives have not been modelled here but analysis can be undertaken with specified objectives. The following five appliance chapters give verbal descriptions of the impact of policy rather than a quantified assessment of their effect on energy efficiency.

## 2.8 CONCLUSIONS

Policy can improve efficiency (and usually reduce consumption) either by improving the energy efficiency of the appliances that consumers purchase or by influencing the way that people use the appliances they own. Initiatives such as information and advice affect both these aspects of energy efficiency, whereas other policies can only affect the range of models purchased. The latter include incentives (through rebates, loans, differential taxation or procurement of new technology) and improvements based on voluntary agreements or minimum efficiency standards.

The characteristics of the appliance and its market determine the most appropriate policies, but the greatest impact will undoubtedly come from a combination of initiatives. The most powerful effects will result when there is at least one policy from each of the main categories: information, intervention and standards.

Policy can be shaped at various political levels, some of which can and some of which will influence the UK Government. EU level intervention on labels and minimum standards require the support of member states, although they are implemented by secondary legislation in the UK. The extent of financial support (eg through advertising and information) are national political decisions. The main developed countries are members of the International Energy Agency, which is devising a series of initiatives on technology procurement. Each country can choose to opt into these programmes. Changes to the level of value added tax on appliances, within certain limits, are properly introduced by primary legislation in UK. It is important for optimising cost effectiveness that these options are developed and assessed together. The effects are synergistic, and aim at market transformation.

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**CHAPTER 3: COLD APPLIANCES** **MARK HINNELLS**

## 3.1 INTRODUCTION

The cold appliances (refrigerators, freezers and fridge-freezers) are the largest single appliance group in terms of total electricity consumption, using 17.1 TWh in the UK in 1994, a figure projected to decline to 15.6 TWh in 2020. The two most important trends that have affected total energy consumption by these appliances are an increased ownership of frozen space, especially in the form of combined fridge-freezers, and a counterbalancing improvement in average energy efficiency.

Refrigeration technology is relatively mature. However, there is a large range of efficiencies on the current market, and considerable further savings potential is available through technologies which are proven and close to market. Consumers at present have a low awareness of energy efficiency. Under the economic and technical potential (ETP) scenario, annual consumption could be reduced to 4.1 TWh, a saving of 11.5 TWh annually by 2020. This is equivalent to the output of two average power stations, and is worth £800 million pa to consumers in saved electricity at 1995 prices. This accounts for 30% of the total savings potential from all domestic electrical appliances.

In order to access this further saving, additional policy intervention would be necessary. This could be aimed at:

- bringing new technologies such as vacuum panel insulation to market through technology procurement;
- expanding the market share of the most efficient appliances (eg through rebates, or differential rates of VAT, together with supporting education programmes for consumers and retailers), and
- increasing the market penetration of the best appliances to 100% through efficiency standards.

This chapter analyses trends, technical potential and policy options. The three cold appliances are in many cases similar enough in general terms (consumer choice, technical options) to be considered together. However, since a freezer compartment consumes considerably more electricity than a fridge compartment, analysis of cost and benefit has to be appliance specific.

## 3.2 LIFE CYCLE IMPACT OF COLD APPLIANCES

Cold appliance manufacturers are under a number of pressures to reduce the environmental impacts of their products. This they are doing by reducing energy consumption in use, phasing out the use of CFCs, HCFCs, and HFCs, and by implementing mandatory recovery of appliance packaging, and recycling of end of life appliances. Cradle-to-grave environmental impact analysis - which assesses the total environmental impact from raw material extraction through manufacture, distribution, use and final disposal - shows that energy consumption in use accounts for more than three quarters of the total environmental impact of the cold appliances over their life cycle (Hinnells 1995).

The projected energy consumption in the absence of further policy intervention is now examined, followed by an examination of the consumption that could be attained with the full implementation of designs that are economically viable and technically feasible.

## 3.3 THE CURRENT MARKET

### 3.3.1 Definitions

Energy consumption of cold appliances is measured under the conditions laid down in the test protocol EN 153. Energy efficiency is the energy consumption per unit service. Thus for the cold appliances this
is litres of storage volume (net of internal fittings) at a particular temperature. In order to compare the energy service provided by different sizes of appliances, the concept of adjusted volume is used, where adjusted volume of a particular appliance is the sum of the volumes of the different compartments weighted by a coefficient (Table 3.1) according to the difference between the internal temperature and ambient test temperature. The coefficient is greater (in other words there is an increase in energy consumption) to maintain a greater temperature difference.

**Table 3.1 Coefficients for adjusted volume**

| | **Internal temperature** | **Coefficient** |
|---|---|---|
| Cellar compartment | + 10°C | 0.75 |
| Fresh food compartment | + 5°C | 1.00 |
| 0 C compartment | + 0°C | 1.25 |
| 0 star compartment | + 0°C | 1.25 |
| 1 star compartment | - 6°C | 1.55 |
| 2 star compartment | - 12°C | 1.85 |
| 3 star compartment | - 18°C | 2.15 |
| 4 star compartment | - 18°C | 2.15 |
| 4 star compartment with no frost or frost free | - 18°C | 2.58 |

Source: GEA (1993: 20 and 30) and Commission Directive 94/2/EC. The additional correction factor for no-frost appliances is of particular note. Auto-defrost or frost free is only a significant energy consumer in freezers and fridge-freezers where the temperature of the evaporator has to be raised by electric heating. A refrigerator cabinet is +5°C so the evaporator plate can be allowed to rise above freezing between cycles.

The test procedure could be improved. There is some variation between manufacturers' data and Consumers Association (CA) tests both on measurements of volume (net of all fixtures and fittings), and on energy consumption over 24 hours, due to allowable tolerances within the protocol. On average, manufacturer-stated consumption is lower than CA measured consumption by 6% for fridge-freezers, and 10% for refrigerators, although in a very few cases the CA tested consumption is up to 135% higher than manufacturer-stated consumption. The test procedure is not a perfect measurement of service. For example, it does not include the ability of a cold appliance to pull cabinet temperature down to a specified temperature and then to maintain that temperature (though such protocols do exist). Many cold appliances are fitted not with a thermostat but with an energy regulator and therefore in the kitchen rather than the test laboratory, they do not maintain the internal temperature specified in the test. The test does not account for the effect of frosting and therefore the effect of frost free operation.

### 3.3.2 Consumers' decision to purchase

Energy efficiency has not traditionally been a significant factor affecting consumers' decision to buy one appliance rather than another (Table 3.2). Consumers focus on size, brand, reliability and price. Mintel suggest that price is reflected by the importance of special offers and trade discounts, but that competition is in any case very price sensitive with limited product differentiation; the cross elasticity between brands is therefore very high (ie a small increase in price of one brand will result in much reduced sales for that brand). However, until energy labelling was made mandatory in the EU in 1995, there was nothing to require the publication of energy consumption data, and therefore to indicate to the purchaser that there was any significant variation between appliances in terms of efficiency, running cost and environmental impact.

Consumers have difficulty understanding running cost data even when they are made available on labels. The consumer has little or no appreciation that, over the life of an appliance, the cost of the consumed energy can be as low as half, or as much as three times the purchase price. Despite this wide variation between models, the purchase price is usually seen as the main factor.

**Table 3.2 Consumer priorities in choosing a fridge-freezer**

| Parameter | % response in 1993 | % change since 1989 |
|---|---|---|
| Fridge-freezer storage ratio | 44 | +7 |
| Well-known manufacturer | 41 | +6 |
| Good service/maintenance guarantee | 37 | -5 |
| On special offer/trade in discount | 30 | +15 |
| British made | 22 | 0 |
| Availability of replacement parts | 19 | -2 |
| * Low electricity consumption | 18 | -1 |
| Frost free | 15 | +1 |
| Low noise | 14 | -8 |
| * CFC-free insulation | 12 | -7 |
| Warning light on defrost | 11 | -7 |
| Ease of storage and retrieval | 10 | -3 |
| Special features (eg auto ice making, drinks dispensers) | 4 | not asked in 1989 |
| Different temperature zones | 4 | not asked in 1989 |

Source: Which three of these factors would be most important to you when buying a fridge-freezer? Survey of 954 adults (Mintel 1993: 19). Another survey suggested that in order of priority, consumers ranked price (58%), running cost (41%), advice from the retailer (40%), manufacturer or brand (36%), colour (24%), and which store it came from (16%), based on telephone interviews with 1,025 adults in December 1994 (BMRB 1994). However it seems likely that in the BMRB survey, 'running costs' to most consumers at present implies *maintenance* costs, since many consumers are not aware of electricity costs. In the 1994 DECADE survey (Chapter 9) only 15% said that energy efficiency was the most important factor.

Even with limited stimulus to efficiency, there is a wide variation in electricity consumption of similar sized models on the current market. Figure 3.1 shows that for a 350 litre fridge-freezer, consumption can vary from 400 to 900 kWh pa, or alternatively, appliances with volumes between 150 litres and

450 litres consume 600 kWh pa. The line shown on this Figure is the regression line through the data points, and illustrates the relationship between volume and consumption.

More efficient machines do not necessarily have a higher purchase price (Which? 1991; Herring 1992; Gross *et al*. 1995). Analysis of price and efficiency of current models shows that there is a good correlation between adjusted volume and price ($r^2$ =0.82), and a weak relationship between price and efficiency ($r^2$ =0.19). Positioning in the market is based on elements other than efficiency. Highly priced models tend to be marketed on the basis of engineering quality, which may or may not include improved efficiency, or on features which carry increased energy consumption (eg auto defrost, which increases energy consumption by nearly 40%).

### 3.4 THE BUSINESS-AS-USUAL (BAU) SCENARIO

Several factors have an impact on changes in the total electricity consumption from cold appliances, including:

- trends in purchasing such as an increased volume of frozen space, in particular through combined fridge-freezers, and additional energy consuming features such as auto defrost;
- technical trends such as improved efficiency of insulation and more efficient compressors;
- trends in patterns of use such as increasing ambient kitchen temperatures, and increasing numbers of fitted kitchens.

In terms of energy consumption, any change in frozen space implies 2.15 times the energy consumption of cold space, and a change in frost-free freezer space implies 2.58 times the energy consumption of cold space (Table 3.1 above).

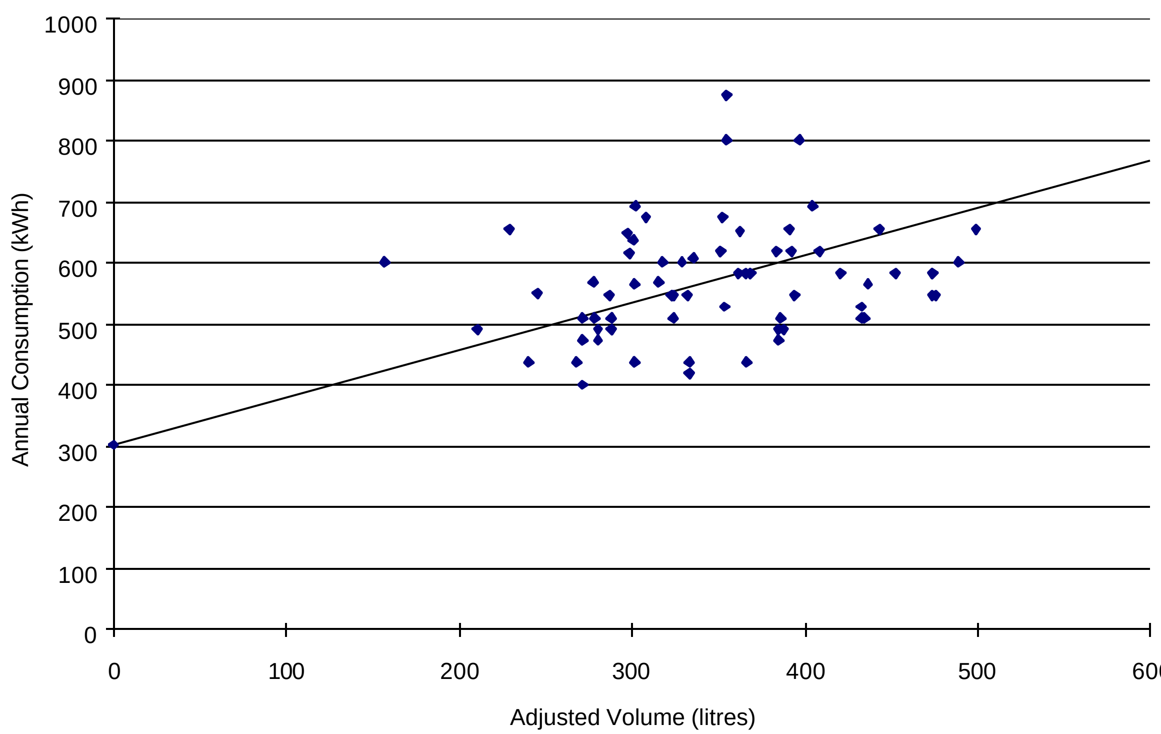


**Figure 3.1 Energy consumption and adjusted volume for UK fridge-freezers (1993)**

### 3.4.1 Ownership and number of appliances

In the UK, ownership of refrigerators has declined from 78% in 1975 to less than 50% in 1994, whilst the proportion of refrigerators with a freezer compartment is also declining. Instead, consumers are tending to buy combined fridge-freezers, or larder fridges with a separate freezer (particularly upright freezers). Almost 90% of households owned some form of frozen space in 1994. Average ownership of any cold appliance is assumed to saturate at 1.5 per household in 2020.

The average size of appliances has changed, though data are sparse. Between 1980 and 1987 there was a 21.5% reduction in the average size of chest freezers, and a 13.9% reduction in the size of upright freezers, equating to a rate of change of 3% and 2% pa respectively. There was no detectable change in the size of refrigerators over the same period, according to GfK data.

Data available to date do not give trends in purchase of appliances with features such as auto defrost, which significantly increase energy consumption. One manufacturer makes 14 models of fridge-freezers, of which 7 are frost free, and one is a low energy model. Both the frost-free and low energy models attract a price premium. An average standard fridge-freezer from one manufacturer consumes 606 kWh pa and costs £439 to buy. A low energy model in the same cabinet design consumes 349 kWh and costs £469 (giving a payback of 2 years over the standard model). A frost-free version consumes 849 kWh and costs £489 to buy. The low energy model costs £29.55 pa to run and the frost free model £67.05 pa to run. If auto-defrost becomes more widespread than at present, energy consumption of the average fridge-freezers and freezers could rise significantly above the level assumed in the BAU scenario.

### 3.4.2 Technical trends

Since no time series of efficiency are available for new appliances on the UK market, they have been derived from a number of sources. Figure 3.2 shows fridge-freezer consumption, but similar graphs have also been developed for refrigerators and upright and chest freezers.

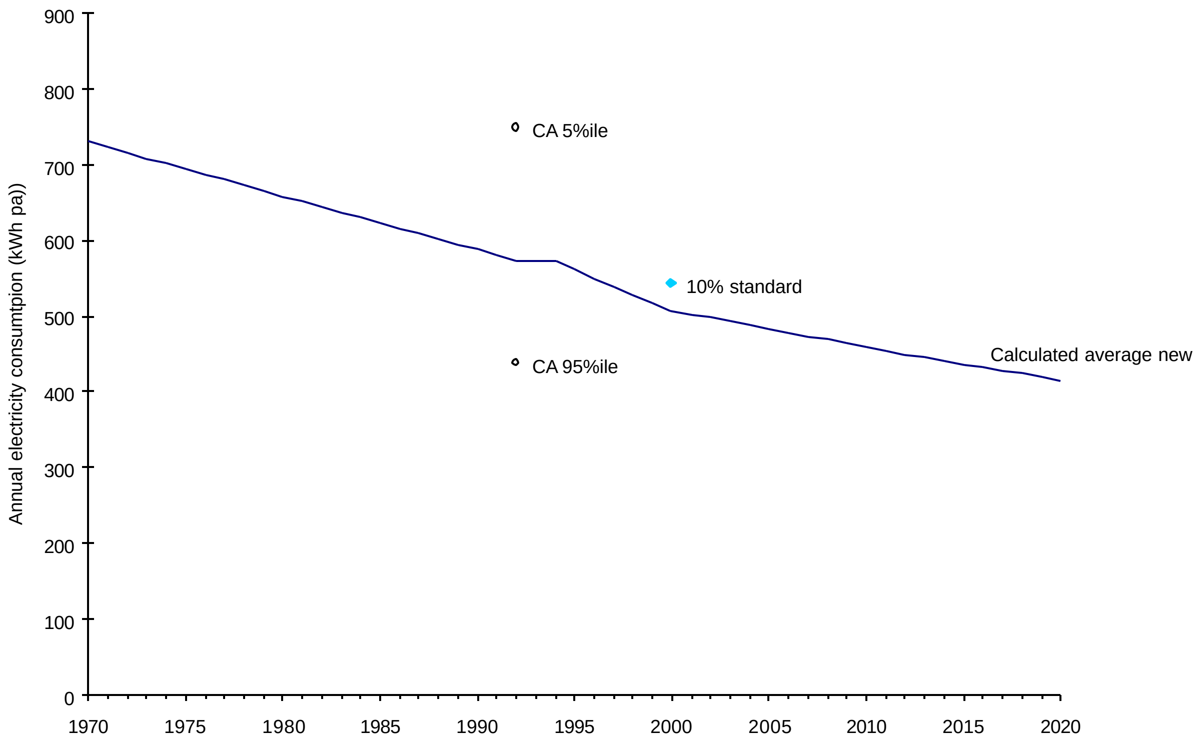


**Figure 3.2 Annual electricity consumption of average new fridge-freezers, UK**

The average new unit energy consumptions (UEC) for all three cold appliances were calculated based on the following data and assumptions:

- German data from ZVEI were collected as part of a voluntary agreement to improve sales-weighted average efficiency (Hass 1992). It has been assumed that UK designs were comparable with German designs at the start of the German voluntary agreement, and that the effect of the agreement was to access economic improvements earlier than elsewhere;
- test consumption data from the Consumers Association (CA) of appliances on the current UK market (shown in 5%ile, average, and 95%ile in Figure 3.2);
- data from the Netherlands which suggest that there was no improvement in efficiency during the period in which CFCs were phased out (van der Sluis and Weijers 1994);
- the basecase projection includes the introduction of mandatory energy labelling on January 1st 1995, and a 10% mandatory minimum efficiency standard currently before the EU Parliament and to be agreed in December 1995, though no second phase minimum efficiency standard or other policy intervention is assumed. Following the introduction of standards, efficiency is assumed to improve at rates at or close to an average of historic rates of improvement. Ownership of frost free appliances is assumed to continue at current levels, though this assumption will need continued analysis;
- measurements of actual consumption of the UK stock are limited to three years: 1982, 1992 (from the Electricity Association) and 1994 (from Lothian and Edinburgh Environmental Partnership LEEP).

A summary of the measured and projected figures used in calculating the annual consumption for each appliance category is shown in Table 3.3. It can be seen that for each of the cold appliances that there is considerable variation between the 5 and 95 %ile of appliances measured by CA; and that following introduction of the proposed minimum standard the average new model offered is still less efficient than the best 5% currently on the market (Figure 3.2 and Table 3.3).

Using the above analysis for the average new appliance, together with a stock model, it is possible to calculate the consumption of the average appliance in the stock in any one year. The stock average lags consumption of average new by around 7 years. For cold appliances, calculations of stock consumption agree well with monitored consumption of the stock in use.

**Table 3.3 BAU cold appliance electricity consumption (kWh pa)**

| | EA 1992 stock in use | Average CA EN153 | 95 %ile CA EN153 | 5 %ile CA EN153 | Draft minimum standard in 2000 EN153 |
|---|---|---|---|---|---|
| Larder fridges | 350 | 270 | 329 | 204 | 260 |
| 3 star fridges | 350 | 337 | 383 | 256 | 304 |
| Fridge-freezers | 620 | 573 | 748 | 438 | 543 |
| Upright freezers | 635 | 459 | 628 | 347 | 432 |
| Chest freezers | 635 | 460 | 589 | 292 | 405 |

### 3.4.3 Comparison of test consumption and actual consumption

While test electricity consumption and actual consumption appear reasonably consistent, test consumption is not directly comparable with actual usage, since the test (EN 153) is conducted with an ambient temperature of 25°C, much higher than is typical of UK homes, and with no food load or door openings. Several factors may modify test consumption in practice. These include the design of any fitted kitchen, latitude and season, and the effects of family size.

One way in which human decisions modify the ability of a cold appliance to remove heat is the siting of appliances. Siting refrigerators next to heat sources (such as an oven or dishwasher) increases energy consumption by some 10-20%. An increasingly important trend appears to be the effect of fitted kitchens. Enclosing refrigerators in fitted cabinets cuts off the flow of air around the appliance and may increase consumption by 10-90% (Sillanpää 1995).

Cold appliance consumption is correlated with ambient kitchen temperature, which is in turn linked to external temperatures. A 1°C increase in external temperature increases average consumption by 1.8%, although some units experienced a doubling in energy use when external temperatures rose from 18°C to 26°C because the appliance could no longer remove the heat load and operated continuously (Proctor 1993). Kitchen temperatures are thought to have risen over the last two decades, and this may imply a 5% increase in cold appliance consumption, though data are not available to confirm this.

Over 80% of the heat load for a refrigerator comes through the wall and doors. Warm air infiltration (during door opening) accounts for around 8% of the heat load, while cooling of products placed inside the fridge accounts for 11% (March Consulting 1990: 37). The 80% is determined by ambient kitchen temperature, the flow of air around the refrigerator, and the quality of insulation. Actual energy consumption varies with household size by a factor of 1.8 (even when removing the effect of size of appliance by a comparison in terms of kWh/100 litres, Sattler 1994). This is probably due to variations in the 20% of heat load that comes from air infiltration from door openings and from cooling of products put in the refrigerator.

### 3.4.4 Total energy consumption

The total electricity consumption projected under the BAU scenario is shown in Figure 3.3.

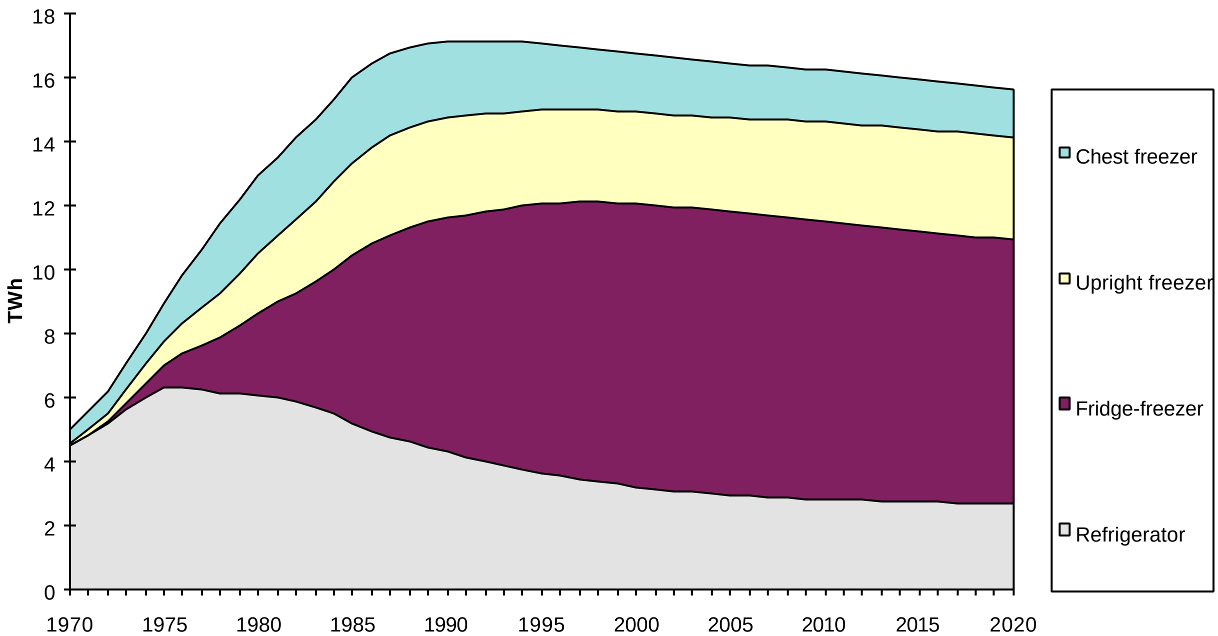


**Figure 3.3 UK cold appliance electricity consumption under the BAU scenario**

## 3.5 ECONOMIC AND TECHNICAL POTENTIAL (ETP) SCENARIO

It has already been noted that there is a significant variation in efficiency on the current market for all three cold appliances, and that there are design options or technologies that are close to market that could improve the efficiency of the average new appliance. The current market is nowhere near to the technological limits. For example, refrigerators without frozen food compartments in the EU consume an average of 301 kWh pa (GEA 1993: 142), but a low energy prototype refrigerator constructed at the Technical University of Denmark consumed 82 kWh. Prototypes in the USA have reached 50 kWh pa while the theoretical limit is as low as 13 kWh pa (Guldbrandsen 1994).

The technical options for all three cold appliances are outlined in detail elsewhere (GEA 1993, Waide and Herring 1993). The cold appliances use energy in removing heat from the cabinet. About four-fifths of the heat load comes through the walls and door insulation. Thus, central to improving efficiency are minimising the heat loss through the walls and maximising the efficiency of the refrigerant circuit. GEA conclude that for most categories of refrigerator and freezer, improving insulation is more cost effective than improving the efficiency of the refrigerator circuit. Options to improve the efficiency of insulation include:

- better door seals;
- better insulation, including reducing heat bridges, thicker insulation with a similar conductivity, or similar thickness with a much lower thermal conductivity such as vacuum panel insulation.

Options to improve the efficiency of the refrigerant circuit include:

- large compressors/evaporators, and a smaller temperature change for the refrigerant;
- condenser fans to improve the rate of heat transfer;
- better temperature control systems in combined fridge-freezers;
- motor optimisers or variable speed compressors, whereby up to 20% savings in motor running costs are claimed when motors are operating on part load.

The GEA methodology is to derive an average for each type of cold appliance based on a statistical analysis of the market, then to derive an additional cost for each design improvement using engineering estimates and market surveys. At the same time, the energy saving from each design option is calculated so that design options can be ranked in terms of cost effectiveness. The cumulative increase in purchase cost, and cumulative energy savings are then calculated. For example, the average larder fridge on the EU market consumes 301 kWh pa. For a 15% increase in purchase price, consumption can be more than halved. The increase in purchase price is paid from the electricity savings within 3.4 years. (GEA 1992: 143).

Another report used the GEA database, methodology and assumptions and computer model, but included a new technology - vacuum insulated panels - the costs of which could not be determined at the time of the GEA report (Waide and Herring 1993). Vacuum panels have a thermal conductance about a quarter or an eighth of that of conventional polyurethane foam. The AEG 275 GSJ-VIP freezer is first product to use vacuum panels in the EU, combining the panels with foamed corner sections. Several companies are developing VIPs including ICI in Belgium, Degussa of Germany, and Owens Corning and GE in the US. The energy consumption for a typical (1992) refrigerator would be reduced by 83% using a thick-walled, single integrated cabinet construction, with a payback of less than two years.

Thus savings of 44-56%, and 80-83% using vacuum panels, were cost effective to the consumer over the lifetime of the product, and are assumed in this analysis to be the Economical and Technical Potential (ETP) for the average new appliance in 2000 and 2005 respectively (Table 3.4 and Figure 3.4). However, even if ETP appliances gained 100% market share in 2000, it would still take time to work through the stock, given that perhaps 1/12 of the stock is replaced in any one year. Thus the full savings would not be made until 2020.

**Table 3.4 Economic and Technical potential (kWh pa) from cold appliances**

| Appliance type | ETP by 2000 (GEA 1993) | ETP by 2005 (Waide and Herring 1993) |
|---|---|---|
| Larder | 301 to 130<br>saving of 56% | 301 to 32<br>saving of 83% |
| 2 to 3 star | 366 to 205 | 366 to 73 |

| | | |
|---|---|---|
| | saving of 44% | saving of 80% |
| Fridge-freezer | 591 to 299 | 591 to 118 |
| | saving of 49.4% | saving of 80% |
| Upright freezer | 440 to 217 | 440 to 88 |
| | saving of 50.6% | saving of 80% |
| Chest freezer | 462 to 241 | 462 to 92 |
| | saving of 47.8% | saving of 80% |

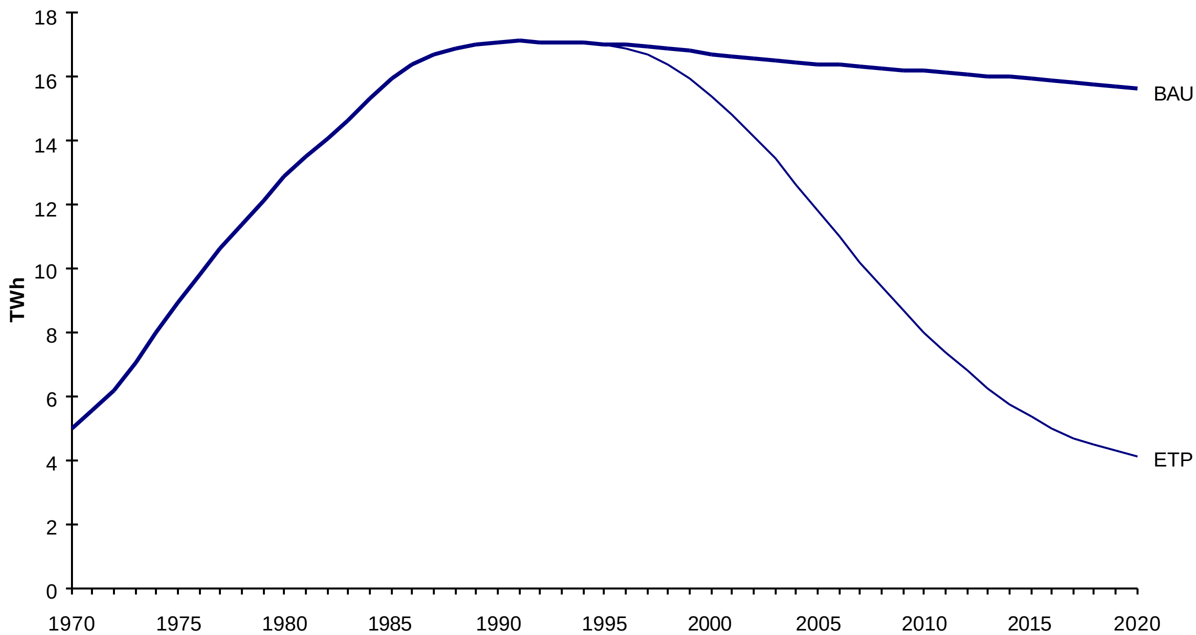


**Figure 3.4 BAU and ETP for the cold appliances**

### 3.6 POLICY INITIATIVES TO ACCESS TECHNICAL POTENTIAL

The issues which are key to a discussion of policy initiatives were raised in Chapter 2 (section 2.3), and have been discussed in this chapter with reference to the cold appliances. In summary:

- a test protocol exists and is widely used;
- statistical analysis shows there to be a wide range of efficiencies on the market at present;
- consumer awareness of energy issues remains low, though the energy label may have raised it from near-zero;
- technical and economic analyses show that a great deal of potential improvement still exists by combining the best known design options, and by bringing new technologies to market;
- the technology has been relatively stable, until the early 1990s when CFCs were being phased out. Frost free frozen space and vacuum panels are two emerging technologies which may make the market more dynamic, and;
- there is some variation in use from a variation in kitchen temperatures and household size, but these are not likely to be influenced by policy. Installation of cold appliances in fitted kitchens could be influenced by policy.

Most initiatives appropriate to the cold appliances affect the technology bought rather than how it is used. Consumption could be reduced by up to 56% using present technologies and up to 83% using new technologies. While these design options increase purchase price, they reduce running costs, and over the life of an appliance, show substantial cost savings for the consumer. There is a wide variety of reasons for efficiency not being taken up at the point of sale, and therefore a wide variety of measures are needed to overcome these barriers.

Lack of information over the difference between two appliances could be overcome by labels at the point of sale. Given that consumers still have difficulty in interpreting the information on the label, and the extent to which they depend on retailer advice, a key element in supporting labelling is the education of retailers to be able to interpret the information on running costs. Such a programme would help reassure manufacturers that investment in improved efficiency would not result in loss of market share through increased cost, but would be a competitive advantage.

Rebates reduce the price of the most efficient products and thus aim to expand their market share (say those in category A and B), as has been developed in the Netherlands, Denmark and the USA (see Chapter 2). The effect of rebates on consumers is thought to be more psychological than economic, acting as clear official product endorsement. Rebate levels should be set substantially above standards levels to provide a genuine additional incentive, or could be graded. A rebate set close to proposed levels for standards would essentially be a cost without additional savings.

Technology procurement reduces the risk associated with launching a new product that is more efficient than anything currently on the market. This could build on the technology procurement exercise by NUTEK in Sweden (see Chapter 2). A particular target for procurement could be vacuum panels, especially those with a thick-walled, single integrated cabinet construction. Vacuum panels represent around 15% of the total ETP available from appliances, and their early market introduction is vital, together with a full understanding of the costs and drawbacks of the technology.

Minimum standards require redesign of the least efficient products by a certain date, and represent a mandatory investment in efficiency at a certain assumed rate of discount. A first round efficiency standard might target appliances in category D, E, F, and G, which would be approximately equivalent to a 15% saving. In the USA, the progressive tightening of efficiency standards in 1990, 1993 and 1998 according to a pre-set timetable provides additional effectiveness and reduces uncertainty for manufacturers. Today's procurement programme can be tomorrow's efficiency standard, as demonstrated in the USA, where the 1998 standards are based substantially on the 1993 Super Efficient Refrigerator Programme (SERP).

The principle of market transformation is illustrated with three distributions shown in Figure 3.5.

- Before intervention: the baseline is the distribution of efficiency for all cold appliances offered by Scottish Hydro Electric prior to the introduction of labelling, where the average model available was an F.
- After labelling: the first stage of market transformation is product differentiation with labels, together with retailer education. The distribution of efficiency of models offered by Scottish Hydro after the introduction of labelling is illustrated. The average model offered moved up to a D (the average of the EU market), with a overall improvement of 19% in a single year.
- Market transformation: a theoretical distribution is illustrated, combining a 15% efficiency standard, plus a rebate and procurement programme. The average appliance becomes a B on the label, equal to a 20% improvement on the current EU average, but still accessing only half of the ETP described by GEA using current energy and equipment prices and excluding vacuum panels.

This process is not static, and the threshold levels for labels, standards, and rebate levels could be revised until the economic optimum or technical limits have been reached.

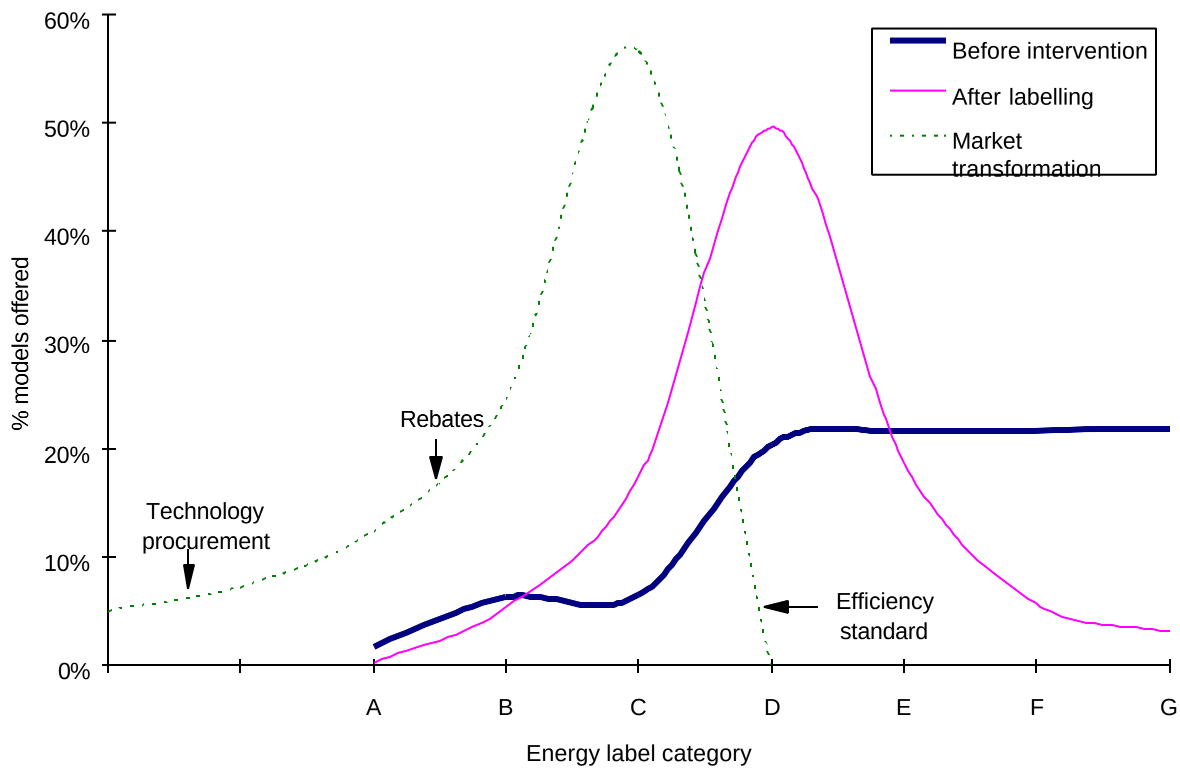


**Figure 3.5 Three stages in market transformation**

## 3.7 CONCLUSIONS

The cold appliances together accounted for 17.1 TWh of UK electricity consumption in 1994. The two most important trends in determining the consumption of the cold appliances are increased ownership (especially of frozen space and frost free); and improvements in efficiency. Under the business-as-usual scenario (historical rates of change with the additional effects of labelling and the current draft mandatory efficiency standards) consumption by cold appliances declines to 15.6 TWh in 2020.

There is a wide range of efficiencies on the current market, and a considerable technical potential for improvement. Savings of 11.5 TWh are technically feasible and economically justified to the consumer over the life cycle.

There are many reasons why efficiency does not form part of the decision to purchase. Market transformation could include: stimulating early market introduction of near market technologies, in particular vacumm panels; expansion of market share of the most efficient appliances through rebates or differential rates of VAT; and underpinning by efficiency standards which increase market share of the most efficient appliances to 100%. While regulatory options are likely to need development and co-ordination at the level of the single European market, many of the incentive-based schemes are most appropriate at national level, for example by the Energy Saving Trust.

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**CHAPTER 4: WET APPLIANCES** **KEVIN LANE**

### 4.1 INTRODUCTION

Washing machines, condensing dryers, tumble dryers, combination machines and dishwashers combine to form the 'wet' appliances grouping, a definition consistent with that used by the EU Group for Efficient Appliances (GEA). DECADE modelled the policy options for this study (GEA 1995) and the results presented here are essentially based on the same analysis.

Currently, the wet appliances represent around 13% of total UK domestic electricity consumption. Projections show consumption in these appliances to be increasing by a further 18.5% by the year 2020, principally due to higher levels of ownership and more households.

This chapter will show the historical and projected consumption by these appliances under the business-as-usual (BAU) scenario, where historical and current trends are projected into the future and do not include the direct effect of any policy.

The business-as-usual scenario is then compared with the reductions that would occur if the full economic and technical potential (ETP) is achieved. Various policy options aimed at accessing this potential, appropriate at the UK and EU level, are then examined. The likely effect of a 10% improvement of new equipment, whether due to mandatory or voluntary agreement is also presented.

### 4.2 BUSINESS-AS-USUAL (BAU) SCENARIO

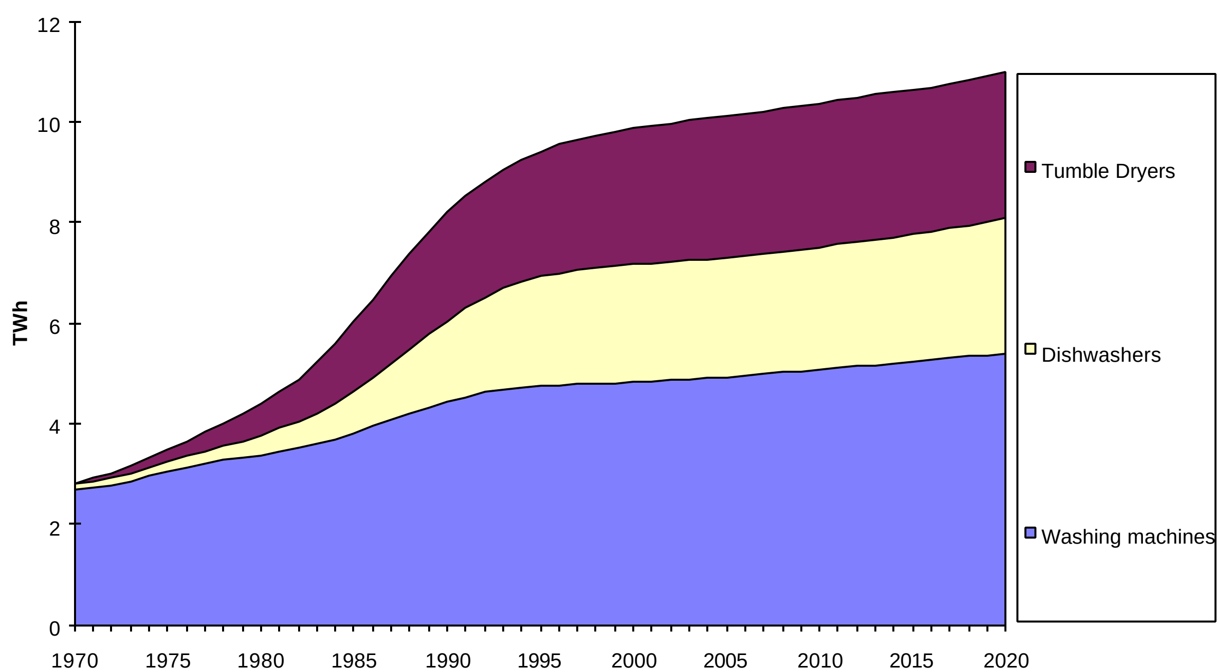


**Figure 4.1 UK electricity consumption by the wet appliances in the BAU scenario**

The BAU scenario in Figure 4.1 shows that electricity consumption is projected to increase from 9 TWh in 1994 to around 12 TWh by the year 2020.

### 4.2.1 Background policies assumed

Historically, energy, water and detergent consumption have been a low priority in consumers' decisions to purchase a wet appliance. This is due to two main factors: firstly, a lack of information on the efficiency (electricity, water and detergent) and hence the running costs of appliances; and secondly, a very high competition on purchase price (March Consulting Group 1990) reducing the likelihood of additional features with lower running costs.

Providing the consumer with more information should increase the importance of energy (and other variables) in their purchasing decisions. The EU energy label, which will become mandatory on all washing machines and tumble dryers from mid-1996, a result of EU Council Directive 92/75/EEC, will provide this information (CEC 1995). In the UK, the eco-label (see Glossary) on washing machines has only been awarded to one manufacturer, and none have been awarded to any dishwashers or tumble dryers on the market.

### 4.2.2 Ownership of appliances

Ownership of washing machines in the UK has steadily increased over the last twenty years, from 65% to above 90% of households owning (or renting), having almost reached saturation point. Ownership of dryers and dishwashers has increased greatly over the last 20 years and is expected to increase further.

Rationalising sales and ownership figures reveals that the average wet appliance lasts around 12 to 14 years, implying that around 8% of the stock of appliances is replaced each year. This time lag must be taken into account when specifying definite levels of savings to be made by specific dates.

### 4.2.3 Trends in usage patterns

There are few surveys of the annual number of uses for washing machines. Data from Denmark and France (Hinnells *et al* 1995) suggest an increase in the number of washes through the 1980s, despite declining household size. This increase has been extrapolated to UK data, since few historical data on washes per annum in the UK are available.

Washes at lower temperatures consume less energy; on average a wash on a 60 ºC programme uses 70% of the energy of a wash on a 90 ºC programme (Møller 1995). There has been a switch to lower temperature washing with the introduction of higher washing performance of machines, better detergents, easier to wash clothing fabrics and improved consumer awareness. Over the past 25 years average wash temperatures have declined by almost 10 ºC, representing a 10% reduction in electricity consumption.

Tumble dryer usage is strongly dependent upon usage of washing machines. For households owning both appliances, it has been estimated that the number of tumble dryer uses is 60% of the number of washing machine uses; the remainder dry naturally, whether inside or outside the house (Siderius *et al* 1995). The length of drying time for each load is dependent on the moisture content of the clothing, which has been declining as a result of increasing spin speeds in washing machines.

Primarily due to a reduction in the average number of people in household owning a dishwasher, the frequency of use of a dishwasher has been declining and has been projected to decline further. As with washing machines, lower temperatures are being used by consumers; again made possible as a result of improved designs using less water and lower temperatures, better detergents and improved consumer awareness.

### 4.2.4 Trends in energy consumption

The average energy efficiency of a new washing machine under test conditions (eg EN 60456:1994) has improved dramatically; there has been a 29% improvement on 90 ºC wash between 1970 and 1994, and a 17% improvement for a 60 ºC wash over the same period, so currently a 4.8kg 90ºC wash will consume around 2kWh (Kemna 1995). These efficiency improvements have been achieved through improved designs requiring less water for washing and also using lower temperatures in the washing process (so a 90 ºC wash may only reach 85 ºC and spend only a small duration at this temperature). Similar levels of improvements have been observed in the efficiency of dishwashers, and currently a fully loaded 12 place dishwasher will consume 1.5 kWh on a 65 ºC cycle (Hinnells *et al* 1995).

In the UK, 90% of washing machines are hot-fill (they use water heated from an external source, usually gas-fired) so the machine requires less electricity per cycle than if the water was heated in the machine itself. The actual savings will depend on the length of pipe run from water heater or tank to machine, as the longer the pipe run the more 'dead' water there will be; for a ½" (1.27cm) diameter pipe every 8 metres of piping contains 1 litre of water.

There has been no detected improvement in energy use per cycle of tumble dryers over the past 20 years, partly due to a lack of data, and where data have been collected it has been under varying test conditions.

With a knowledge of number of appliances, average energy consumption of new machines, the usage levels and lifespan of these appliances, total electricity consumption in GWh may be estimated (where the effect of hot-fill machines is taken into account) and is summarised in Figure 4.1. To check this calculation, the estimated unit energy consumption figures (UEC; the average consumption by the average machine, calculated by dividing the total electricity consumption in one year by the total number of machines in the stock in that year) are compared with measured samples, such as Electricity Association (EA) measurements. An example of UEC figures for washing machines is given in Figure 4.2.

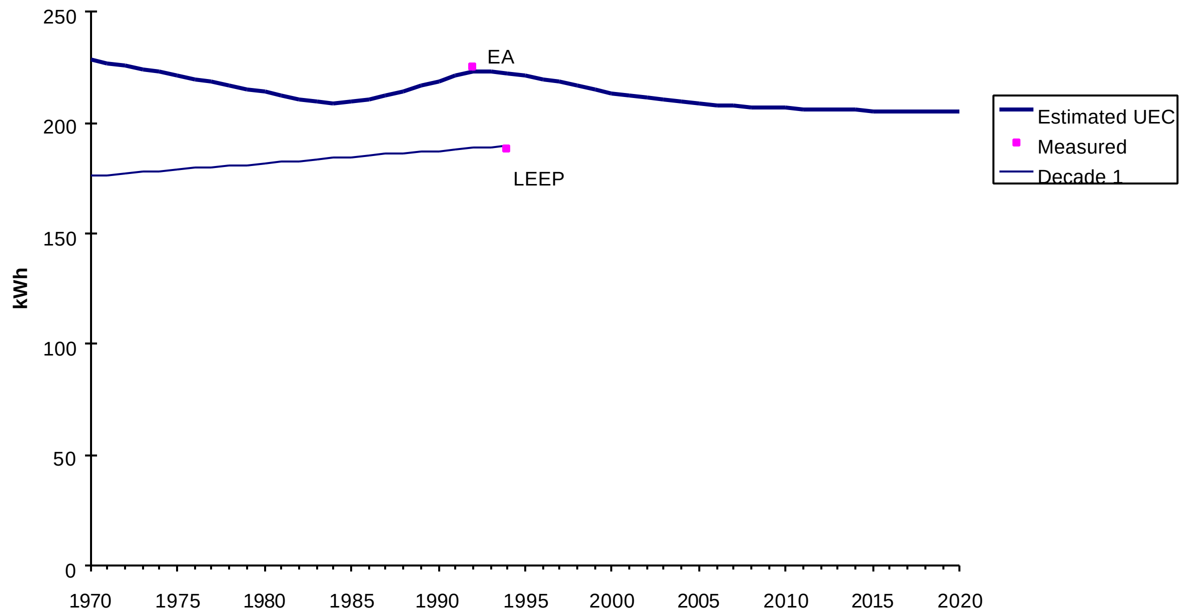


**Figure 4.2: Estimated and measured UEC for UK washing machines, BAU**

The EA measured average consumption (UEC) in 1992 and their figure compares well with the estimated UEC from the stock model. The EA sample is relatively small and may contain a slight bias towards the higher income households which is a result of the sample selection procedure. The estimated rise in UEC consumption in the 1980s is due to the increase in the frequency of washes. The UEC used in the first DECADE report is also included to show the upward revision made.

### 4.2.5 Discussion of the BAU scenario

Total electricity consumption is projected to increase further for all three wet appliances, principally due to rising ownership and households (from 23.5 million in 1994 to a projected 28 million by 2020) and despite assumed decreases in temperatures (for washing machines and dishwashers) and improvements in energy efficient technologies.

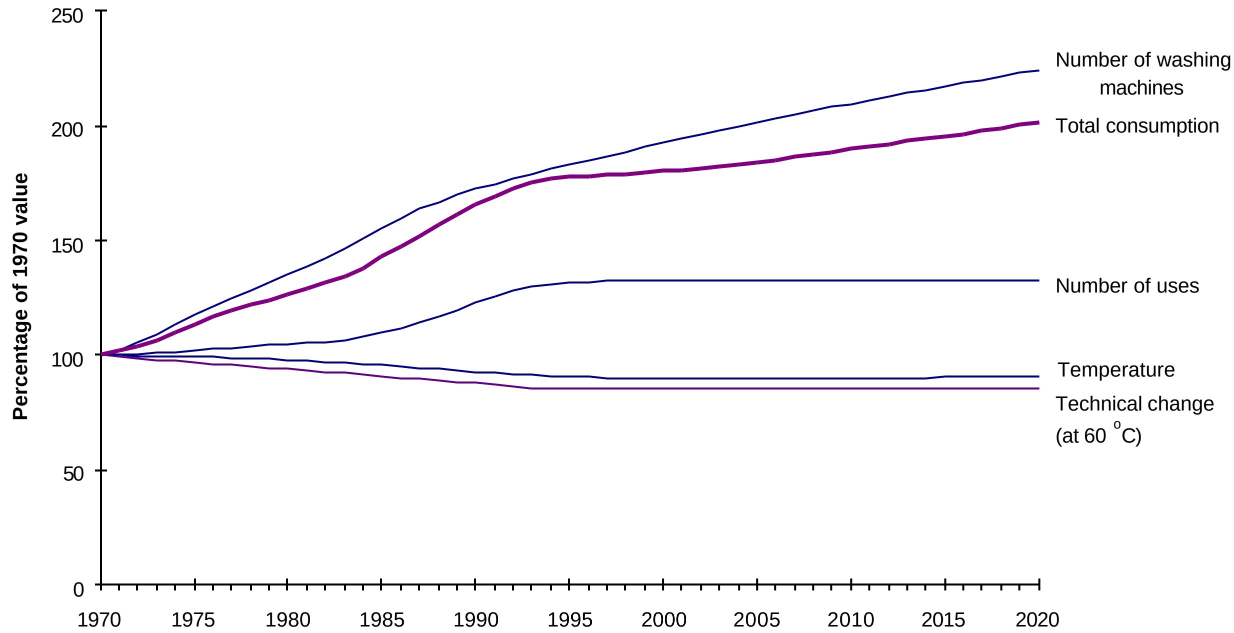


**Figure 4.3 Indices of washing machine variables (base year = 1970)**

To summarise this through time, a graph of indices is presented, for washing machines only, with 1970 as the base year (Hinnells and Lane 1995). All these indices together result in an increase in total energy consumption. The use of indices identifies those factors that effect electricity consumption and reveal which policies may be relevant (Figure 4.3). They are:

- number of appliances: the rate of change may slow down in a recession or increase when the economy flourishes, but otherwise is not influenced by policy;
- number of uses: affected by education programmes and awareness campaigns;
- temperatures: the mix of temperatures chosen by users depends on clothing, labels on clothing, detergents, and can be influenced by education or broader collaboration with detergent manufacturers and the clothing industry. Sometimes reduced by technology change;
- technology change: these are most affected by policies such as minimum energy efficiency standards, procurement programmes, rebates (if bought), R&D subsidies.

## 4.3 THE ECONOMIC AND TECHNICAL POTENTIAL (ETP) SCENARIO

This scenario examines the maximum savings that can be made through the introduction of cost effective and available technology. The ETP scenario represents those technical improvements that are already proven and are economically feasible at 1994 energy and water prices. The level that has been chosen is via a life cycle costing carried out for GEA (Kemna 1995).

By the year 2020, the generation of almost 3.5 TWh may be avoided by actions which are economical to the consumer at today's prices; a summary is given in Table 4.1. Also shown are the effects of a 10% reduction whether introduced through a mandatory or voluntary agreement.

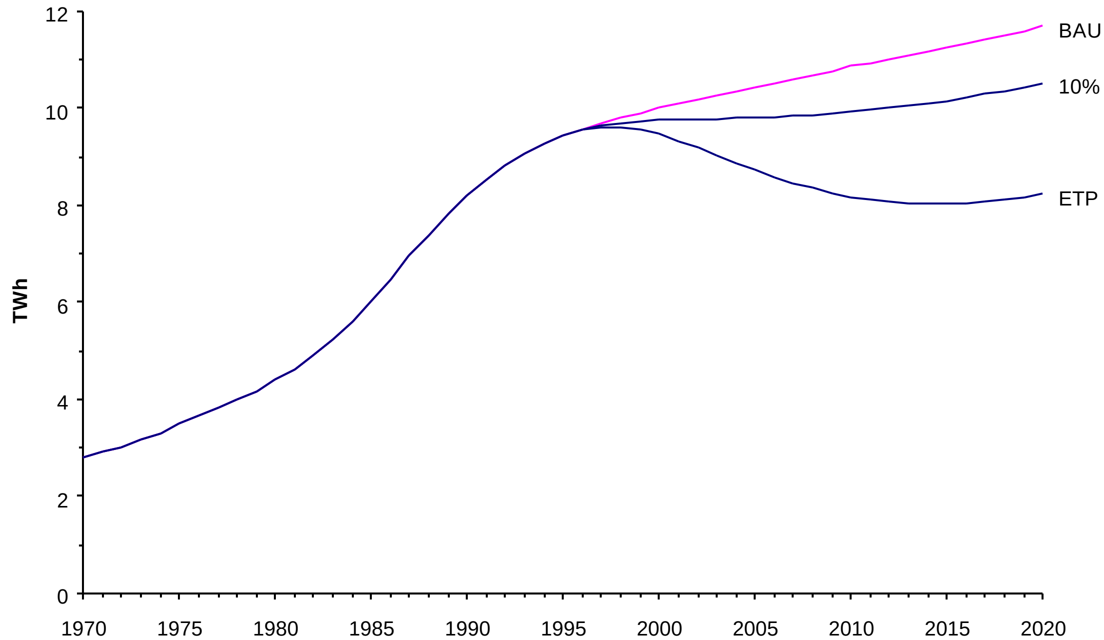


**Figure 4.4 Electricity consumption in the UK under the BAU and ETP (and 10% standard) scenarios for the wet appliances**

**Table 4.1 Summary of BAU and ETP scenarios of electricity consumption by the year 2020**

| Appliance type | BAU (TWh) | 10% (TWh) | ETP (TWh) | Potential saving (BAU-ETP) (TWh) |
|---|---|---|---|---|
| Washing machine | 5.4 | 4.9 | 3.8 | 1.6 |
| Dryers | 2.9 | 2.6 | 2.4 | 0.5 |
| Dishwashers | 3.4 | 3.1 | 2.0 | 1.4 |
| **Total** | 11.7 | 10.5 | 8.2 | 3.5 |

Design options for washing machines, dishwashers and dryers are given by GEA (1995). For washing machines and dishwashers these options involve improved use of water, improved loading (dishwashers only), longer duration washes and lower temperature washes.

The technical design options for washing machines (GEA 1995) in cost effective order are:
- improved water level control;
- longer time, lower temperature, including biostep (or, alternatively, improved mechanical action);
- basic improvement of thermal efficiency, and
- reduction of tub-drum clearances (larger drum).

Technical design options for dishwashers (GEA 1995) in cost effective order are:
- lower hot rinse temperature of 55 °C;
- lower wash temperature of 55 ºC and longer wash cycle;

- alternating spraying of top and bottom spray arm;
- cross-flow heat exchanger between water in- and out-let, and
- improved thermal efficiency (reduced thermal bridges).

Improvements to dryers are much more difficult to assess, partly due to lack of knowledge about usage. Kemna (1995) gave some tentative technical design options for dryers, principally:

- higher air-flow;
- re-circulation of air, and
- heat exchange.

All of the above design options for the three wet appliances were modelled mathematically and then tested experimentally in a laboratory to ensure that they were feasible (CTTN-IREN 1995).

## 4.4 POLICY OPTIONS

In summary, there is a wide range of efficiency on the market at the moment for washing machines dryers and dishwashers. There is a large economic and technical potential for washing machines and dishwashers, but less so for dryers. Consumer understanding is relatively low except perhaps for dryers. Behaviour causes large variation in consumption especially with regard to machine loading, wash temperatures and spin speed. To attain the savings identified in the ETP scenario, various policies or combination of policies may be employed. Broadly they may be categorised into information to consumers, incentives and regulation.

### 4.4.1 Information

Information for consumers available at the point of sale includes energy labels, appliance lists and eco-labels and will influence the choice of machine purchased. The EU energy label for washing machines has been approved by the European Commission (Figure 4.5). The likely effect of this measure is uncertain as the label lists other information, including wash performance (rated good A through to poor G), spin speed and noise. The complexity of the washing machine label may mean that the effect is limited, though retail training may improve effectiveness. The EU energy label for tumble dryers is set to be introduced at the same time as the washing machine label. At present EU energy labels on dishwashers cannot be introduced due to the lack of an adequate test procedure to measure wash performance.

Eco-labels on washing machines have had little effect to date. This is partly attributable to a low visibility, since only one manufacturer has been awarded the label. No manufacturer has to date applied for an eco-label for dishwashers. The criteria for the label are to be revised in 1996.

Other approaches would be needed to influence the way consumers use their machines to wash and dry clothes and dishes. Consumer education has considerable savings potential with the wet appliances. These could include the role of Eco-buttons, the effect of wash temperatures and loading levels, and the importance of higher spins speeds in washing machines, especially when a tumble dryer is to be used, to further reduce the moisture content of clothing.

### 4.4.2 Economic incentives

Economic incentives will usually require a unified information scheme, such as a product list system or a labelling scheme, or both. Rebates can be offered on the more efficient appliances. Rebate schemes for the wet appliances are in operation or planned in the Netherlands and Germany. Rebates produce a consumer and a manufacturer response and the psychological impact may be more important than the effect on pay back calculations. Rebates could focus on machines in category A and B of the energy label for energy consumption, wash performance and spin efficiency.

**Figure 4.5 The EU energy label for washing machines**
Source: CEC (1995)

NUTEK, in Sweden, has had a programme to design a washing machine with a smaller wash load more suitable for smaller households which were found to under-load their machines much of the time (NUTEK 1993). Procurement programmes to introduce more energy efficient wet appliances are also being investigated under the auspices of the International Energy Agency demand-side management programme.

### 4.4.3 Regulation - Minimum energy efficiency standards

The Danish Government notified the European Commission in August 1994 that it intended to introduce mandatory minimum efficiency standards for washing machines and dishwashers (DEA 1994). The Commission response has been that it would try and negotiate a voluntary agreement with the manufacturers and this process has been started with representatives of washing machine manufacturers.

Figure 4.4 shows the effect of a 10% standard applied to all three wet appliances. Several technical options become economically justified if energy and water prices rise (GEA 1995, Figures 5.2, 5.3 and 5.6). Of those not included as economically-feasible at the moment, more are affected by an increase in water prices than energy price changes.

### 4.4.4 Fuel switching and infrastructure

Fuel switching offers an effective means of reducing carbon dioxide emissions, by a change from a carbon intensive fuel (eg coal fired electricity) to a less carbon intensive fuel (eg gas) at a higher overall efficiency (approximately from 35% to 60%). This potential includes the wider use of gas-heated dryers and dishwashers where the water is heated externally to the machine. 90% of UK washing machines already have the capability to heat water externally. Other reductions in $CO_2$ emissions could come where the house is linked to a district-heating system or uses oil-fired water heating. Most of the wet appliances heat both water and air with electricity, though a number of gas utility companies now lease gas dryers.

## 4.5 CONCLUSIONS

Energy consumption by the wet appliances is still set to increase, primarily due to the increased number of machines; higher ownership of tumble dryers and dishwashers and an increasing number of households. It is not expected that these increases will be negated by improvements in efficiency, reduced frequency of number of washes and the use of lower temperatures.

There is scope to improve the average efficiency of new washing machines and dishwashers by around 30% using technology options that are already available and cost effective to the consumer over the lifetime of the product. The cost effective reduction for tumble dryers is less certain, and also smaller, and a reduction of around 10% has been identified. These reductions, if achieved, would mean that consumption in 2020 would be lower than 1994 levels even accounting for a larger number of wet appliances.

EU energy labels will be introduced, the effect of which is difficult to predict, especially on washing machines. The effect of the energy label on tumble dryers, however, may be more significant since consumers are already aware of running costs. The success of this and any other labelling scheme will be enhanced if retailers are informed, as preliminary results from the cold appliance energy labelling scheme suggests.

The introduction of a 10% minimum energy efficiency standard will access some of the ETP, but only a part. Since there are only a few major manufacturers of wet appliances operating within the EU the swiftest introduction of standards would be done through a voluntary agreement with these manufacturers.

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## CHAPTER 5: BROWN GOODS GEOFF MILNE

### 5.1 INTRODUCTION

This chapter covers home entertainment electronic equipment – televisions (TVs), video cassette recorders (VCRs), satellite and cable TV, and audio/hi-fi equipment – the appliance group known as 'brown goods'. Few markets are as dynamic and competitive as the audio/video market. Products with 'new' features are constantly appearing on the market. The appliances can be characterised as having most of the following features which, in combination, distinguish them from other categories:

- ownership, which includes rentals, is often greater than one item per household;
- there is a rapid rate of technical change, which makes predictions about future developments very difficult;
- standby power demand is a significant factor;
- there is little energy awareness amongst consumers - purchasing decisions are very largely driven by feature (including styling) and price.

### 5.2 STANDBY CONSUMPTION

Although present in some other appliance groups, such as microwaves with an electronic clock-timer, the standby function is most prevalent in home entertainment equipment. Standby can be defined as a mode of operation where energy is consumed even when the appliance is not being used for its primary designed purpose. For example, a TV is designed primarily to produce pictures and sound, but when turned off with the remote control and therefore not performing this function, energy is being consumed for the convenience of being able to turn it on without having to use the switch on the set itself. Whilst acknowledging that some people might need the facility of remote control operation, which is the major contributor to standby, the standby mode is often a matter of convenience rather than function, and the associated energy consumption is incidental rather than intentional on the part of the user. If turned off with the switch on the set, a TV consumes no energy. With many other appliances, there is no switch on the unit itself which disconnects the supply - it is either in the on or standby mode unless turned off at the power socket.

Standby is becoming an increasingly important part of base-load electricity consumption even though individual appliances use only a small amount of energy. In total, standby may account for about 5TWh pa in the UK in 1994, or the equivalent output of one large power station. Consumption is rising however, as more and more remote control products come onto the market. Almost all brown goods now sold have a remote control capability. There are also many other products that are increasing in number which can have transformers permanently connected to the supply, such as battery chargers and halogen desk lamps, and are therefore consuming energy unless actually unplugged, but these will not be considered in this chapter.

### 5.3 BUSINESS-AS-USUAL (BAU) SCENARIO

Figure 5.1 shows the historic consumption and BAU projection. Constructing a BAU scenario for some of the appliances in this group is difficult as there is very little information on usage patterns (eg with hi-fi) and because some (eg satellite and cable TV systems) have only been on the market for a short time. The following section deals with each equipment type, summarising trends and assumptions behind the BAU projections, before examining the ETP and policy options.

The large drop in TV electricity consumption from the mid 1970s is largely due to changes in the technology as outlined below.

### 5.4 TVs

#### 5.4.1 Ownership

TVs have the highest household ownership level of any single appliance in the UK, about 98% in 1994 compared to 91% in 1970, and is now virtually saturated (FES 1995). Over the same period, the number

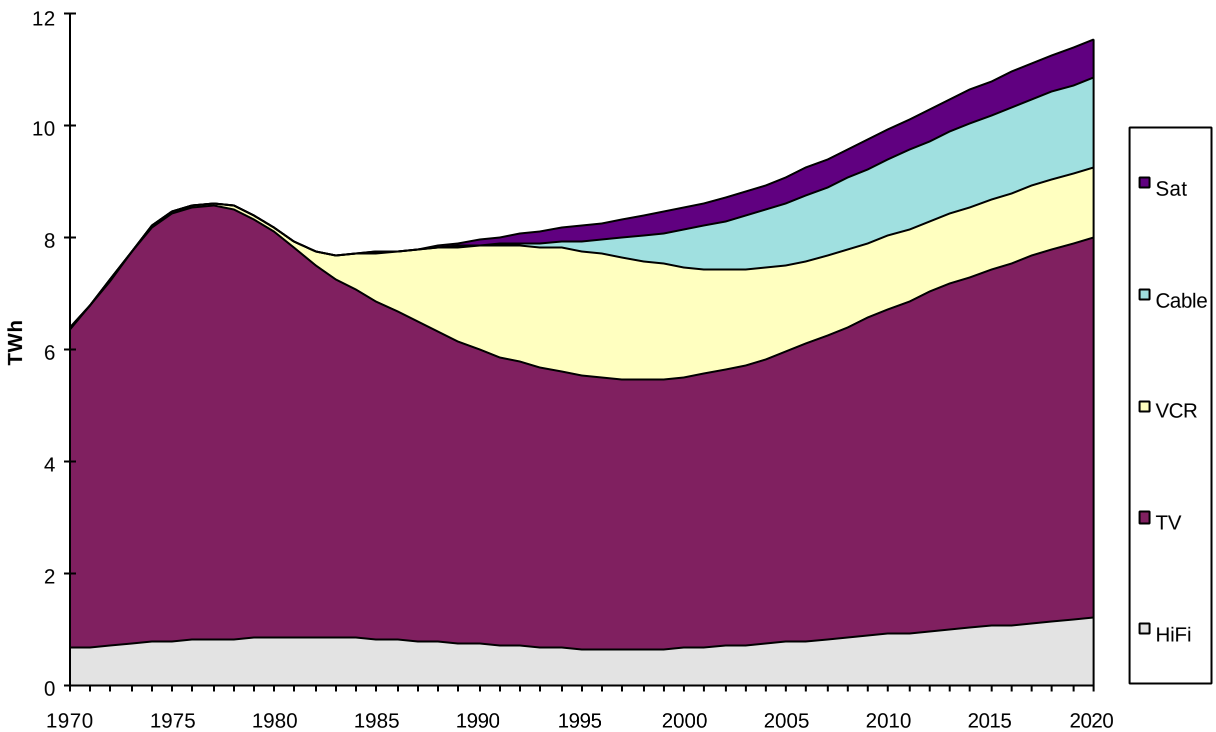


**Figure 5.1 Historic and projected BAU consumption for the brown goods**

of TVs per household increased from 0.91 to 1.7 due to the increase in ownership of second and third TVs as shown in Table 5.1(Datamonitor 1992, Mintel 1987, AGB 1992, EAO 1994) . In the USA there are currently 1.95 TVs per household, and this figure is expected to rise to 2.15 by 2020. At present the UK lags the USA by about 20 years (US DOE 1993). It is therefore not unreasonable to expect that there could be 1.9 sets per household by 2020 and that the number could ultimately exceed 2.

Remote control TVs first appeared on the market in the late 1970s, and now acount for 99.5% of all new sales. By 2005 all the main TVs in households will be remote controlled and by 2010 all TVs will be. Ownership of remote control sets is important because of their standby consumption.

**Table 5.1 The number of TVs per household in the UK, 1970-2020**

| Year | Total | Main | | Second | | Third | | Total sets (millions) |
|---|---|---|---|---|---|---|---|---|
| | | All | RC | All | RC | All | RC | |
| 1970 | 0.91 | 0.91 | - | - | - | - | | 17 |
| 1980 | 1.20 | 0.97 | 0.10 | 0.20 | - | 0.03 | - | 23 |
| 1990 | 1.60 | 0.98 | 0.59 | 0.49 | 0.13 | 0.13 | 0.03 | 36 |
| 2000 | 1.79 | 0.98 | 0.96 | 0.60 | 0.48 | 0.20 | 0.16 | 44 |
| 2010 | 1.88 | 0.99 | 0.99 | 0.66 | 0.66 | 0.22 | 0.22 | 50 |
| 2020 | 1.92 | 0.99 | 0.99 | 0.70 | 0.70 | 0.22 | 0.22 | 55 |

(RC = remote control)

### 5.4.2 Technical developments

The on-mode power of TVs has been reduced greatly over the past 25 years, largely due to technical changes as the electronic circuitry has changed from valve (vacuum tube) to transisitor and finally to integrated circuit technology. As a result, the average power demand of new TVs on the market has fallen from around 250W in 1970, to 100W in the early 1980s and to 70W in 1994. An increase in the ownership of smaller screen sizes has also contributed to this trend, as power demand in the on-mode is almost directly proportional to screen size. As a result, total energy consumption in the on-mode has been steadily falling since the mid 1970s, but is expected to start rising again in the near future due to:

- rising ownership levels;
- increasing household numbers;
- rising power demand due to larger screen sizes and more features;
- an increase in the number of viewing hours per household even though the average number of people per household is falling.

The on-mode power demand is likely to increase slightly in the future due to an increase in larger screen sizes with the expansion of wide screen (16:9 ratio) picture transmission, and extra features such as NICAM stereo. This effect has already been observed in Japan (Tsutsui 1994). Based on the predicted sales of the different screen sizes, average new power demand is expected to rise to about 80W by 2010. Although some future developments, such as LCD screens, may reduce power requirements these are a long way off commercial release except for very small portable sets.

### 5.4.3 Usage

Data on patterns of TV viewing and radio listening comes from Broadcasters' Audience Research Board (BARB), a company which conducts audience surveys on behalf of their joint owners: the BBC and ITV. In line with other European countries, average viewing hours per household in the UK have been rising steadily over the years (even though the average household size has been falling) from 4.5 hours per day in 1970 to just over 6 hours per day in 1994. This is projected to rise to 7.5 hours by 2020 as a result of the introduction of more terrestrial channels and the spread of satellite and cable services encouraging more 'time-shift' viewing (ie watching a recorded programme at a later time).

Households with satellite and cable currently watch about 5% more TV than those without (BBC 1992). Also, households with a VCR record more than twice as much as they actually playback and view, so there may be a latent demand for more viewing if the time or equipment was available (ie a second TV or an in-house distribution network).

The BBC states that their research has shown that 90% of the annual variation in viewing hours can be explained by the weather; temperature and hours of sunshine (Day and Cowie 1990). For example, average winter viewing hours per person in 1990 were about one hour per week less than in 1989 due to the exceptionally mild winter in 1990 (BBC 1991). Apart from the effect on TV viewing, this has a follow-on for other energy uses, such as kettles and lighting, which people will tend to use more if in the house for a longer period.

Standby power is independent of the TV screen size and features. Since remote controls were introduced in the late 1970s, there has been a small drop in standby power demand from around 10W to 8W in 1994 (Novem 1995). This indicates that the present trend will result in only a small decrease in standby in the future. However, as part of their voluntary target value scheme with manufacturers, the Swiss Government has negotiated for the standby power of TVs sold in Switzerland to be reduced to 5W by January 1996 and to 3W by January 1998 (Swiss FOE 1993). This will have some impact on the EU market. Future development is therefore taken as a mixture of the present rate of autonomous change and the Swiss target values, based on a study undertaken for the EU (Novem 1995).

Total energy consumption in the standby mode is largely dependent on whether users turn the TV off with the remote control or with the switch on the set. Research in a number of EU countries indicates that an average of about 55% with a remote control set use the remote control (Novem 1995). A survey by Friends of the Earth in the UK in 1989 estimated that 7 million sets were left in the standby mode overnight, which was about 45% of all remote control sets (Ethical consumer 1992). Although additional features do not necessarily increase standby power demand, some technical changes which lead to changed usage patterns may do. For example, connection to ‘in-house’ networks or combined TV/VCR appliances which may replace TVs but have the standby use of a VCR (see next section), may lead to higher overall energy consumption. Sales of TV/VCRs are increasing very rapidly in the USA, but their future is uncertain due to other technologies such as the video disc. This analysis assumes that TVs will be used in much the same way in the future as they are today. Table 5.1 shows the estimated and projected electricity consumption.

**Table 5.2 TV electricity consumption 1970-2020 (TWh)**

| Year | On-mode | Standby |
|---|---|---|
| 1970 | 8.3 | 0 |
| 1980 | 8.9 | 0.06 |
| 1990 | 5.3 | 0.28 |
| 2000 | 4.3 | 0.36 |
| 2010 | 5.3 | 0.30 |
| 2020 | 6.2 | 0.31 |

## 5.5 VCRs

### 5.5.1 Ownership

The number of households owning one or more VCRs has increased rapidly over the past 20 years, and stood at 73% in 1993. Ownership of second VCRs was 0.15 per household in 1993 taking current overall ownership to about 0.9 per household (AMA 1994). Although growth in ownership will continue for some time, it will be limited by services such as pay as you view via cable networks, and is projected to saturate at 1.15 per household by 2020.

### 5.5.2 Technical developments

Unlike TVs, VCRs effectively do not have an off-mode. The switch on the unit itself performs the same function as the remote control: it puts it into standby or on-mode. The VCR can therefore only be truly turned 'off', that is consuming no electricity, by disconnecting it from the electricity supply.

There is little historic information available for on-mode power demand, but it will have gradually reduced over time as the technology of VCRs has changed from transistors to integrated circuits. Recent measurements show that it was about 20W in 1994 (Novem 1995). The introduction of features such as NICAM and perhaps more powerful motors to speed up rewind times mean that it is unlikely that this will reduce much further.

Similarly, there is little historic data on standby power demand. Recent data suggests a fall from 11.5W in 1991 to 10W in 1994 (Novem 1995). As for TVs, the Swiss Government has negotiated a voluntary target agreement for VCR standby consumption with manufacturers. This requires a standby power demand of no more that 7W by January 1997 and no more than 3W by January 1999. This will have some effect on the EU market, and a combination of the current trend and the Swiss targets has been used to arrive at the BAU projection.

### 5.5.3 Usage

There is little historic data on the usage of VCRs as this was not included in the BARB figures until very recently. The 1992 figures showed that households owning a VCR recorded 4.8 hours of programmes per week, played back 2 and played rented or bought tapes for 2.6, giving a total of 9.4 hours per week, or 1.35 hours per day. As more channels become available, more time shift viewing may occur which could increase this figure, but on the other hand, an increase in pay-to-view may reduce the watching time of rented tapes. It is therefore assumed that the usage will remain at its present level. A small rise in total consumption is therefore expected by 2020 due to rising ownership and household numbers.

Standby usage for VCRs is substantially determined by the on-mode usage, as VCRs are generally in standby when they are not being used to play/record. Consequently, most VCRs are in standby for 22.65 hours per day, which is 95% of the time. Their only function during that time, if not set up to automatically record, is to keep the clock time setting.

## 5.6 SATELLITE AND CABLE TV

The rate of growth in the satellite equipment market has been more dramatic than any other consumer electronic product. At the end of 1993, 12% of households had a direct broadcast by satellite (DBS) system and installations were running at about one million pa and beginning to level off. About 3% of households had a cable connection in 1993. BARB estimate that the percentage of households with either installed was 17.1% in November 1994. It is expected that the two systems will have risen to a total of 50% of households by 2000. The integration of decoders into TVs and VCRs could lead to reduced overall consumption as there would be one source of standby loss instead of two, but as there is little information on the develpment of this market, this analysis assumes that they will remain as separate items.

There is very little information available on the power demand in either the on or standby modes.

In 1993 viewing in owning households was 9.2 hours per week, similar to VCRs in the on-mode (CTA 1993). It is assumed that they are not turned on when not actually being watched. As for VCRs, they are in the standby mode when not being used and standby therefore accounts for 95% of usage time.

## 5.7 AUDIO EQUIPMENT

The most significant trends with audio equipment are the switch from separate component based hi-fi systems to integrated music centres and the increase in the number of remote control units on the market. Music centres are now the most popular type of audio durable and owned by about 35% of households in 1992. A survey in the Netherlands in 1994 found that about 45% of audio systems had a remote control facility (Novem 1994), and ownership is projected to reach 100% by 2020.

Data for the usage of audio equipment are very limited, as surveys usually do not differentiaite between portable and non-portable equipment or even in-car systems. It is estimated that in 1993 home audio systems were used for approximately 17 hours per week, and this had risen from 15 hours in 1970 .

The power demand in the on-mode will have fallen over the years due to the change from valve to solid state technology. Estimating a figure for the actual on-mode power demand however is very difficult as it depends very much on the volume level used. One source found average values of 16 watts in the ‘normal’ listening mode and up to 48 watts in the ‘party’ mode (Nielson and Anderson 1995). A value of 20 watts is assumed for this analysis and is assumed constant for the BAU projection.

Most audio products currently sold, including almost all music centres and many ‘portable’ CD/cassette players, have a remote control facility. It is assumed that by 2000 all will be except for the lower priced radio cassette units. Similar to VCRs, these usually cannot be turned off by the power switch on the unit itself (especially as many now incorporate a clock) but must be disconnected from the mains supply. There is no known historic information on the standby power demand of audio equipment. A Dutch survey found an average value of 15W in 1994 and a Swedish study estimated 6W in (Novem 1994, Sandberg 1995). This will vary depending on the type of system. A value of 8W is asumed here. This is similar to the figure for VCRs. No improvement is assumed without policy intervention. At present no policies are in place to deal with audio standby, although measures such as voluntary targets for TVs and VCRs could be introduced.

The Dutch study found that most remote control audio systems are either always or never in standby mode and the average time in standby per day was just under 7 hours. However, as more and more come with a built-in clock timer, it is likely that an increasing percentage will be operated with the remote control and the time in standby will increase.

### 5.8 THE IMPORTANCE OF STANDBY

The on and standby modes are of different relative importance for different appliances. This has implications for policy decisions. For example, with TVs the on-mode accounts for about 90% of the total energy consumption, whereas for VCRs standby is 90% of the total. Figure 5.2 shows the proportion of on and standby consumption for TVs and VCRs in 1995 and 2020.

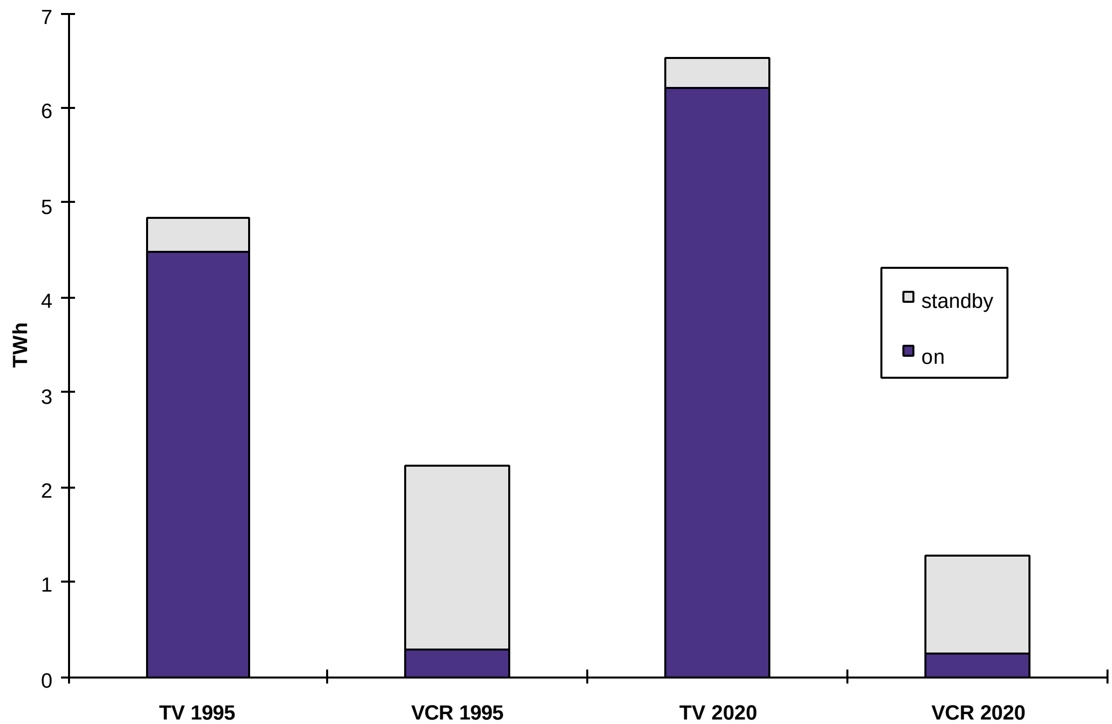


**Figure 5.2 On and standby BAU for TVs and VCRs in the UK, 1995 and 2020**

### 5.9 FUTURE DEVELOPMENTS

Since this is an area of such rapidly changing technology, prediction of possible developments is very difficult. However, one concept which could have a significant impact is the 'home theatre', based around a very large screen TV with high quality picture and incorporating a stereo sound system. Such systems are already selling in significant numbers in the USA, where large screen (up to 40") sales are rising rapidly (by as much as 35% pa in 1994 for one manufacturer). Projection systems are also incteasing in number, with US sales up by 30% in 1994 over 1993 (Dzierwa 1995). Also on the horizon are 3D TV, flat screen, picture-in-picture and high definition.

Added to this is the rapid spread of information technology which is blurring the line between personal computers and televisions, with a number of products already on the market which combine both in the one package. A rise in the amount of tele-working or facilities such as home shopping and banking services could influence considerably the way in which these items are used.

Industry does not expect that there will be a complete merging of TVs and PCs. Although each will take on more of the features of the other, especially as TVs become more interactive, they will remain essentially differentiated products, with TVs providing entertainment and information and computers remaining task based and becoming more user and use specific, such as energy management. It is difficult to predict how this market will develop in the future, as the current younger generation is the first to grow up with such a degree of exposure to information technology. A recent survey by Microsoft in the USA found that 57% of children asked said they had helped an adult use a computer during the past 12 months! (Davis 1995) Whatever form the market takes, it will be large. Home computers are dealt with in Chapter 8 of this report.

## 5.10 ECONOMIC AND TECHNICAL POTENTIAL (ETP)

Apart from TV and VCR standby, there has been no engineering analysis of costs to the manufacturer or consumer of implementing technical measures to reduce brown goods' power demand. Hence an economic analysis has not been carried out and it is therefore not possible to deduce a figure for the economically viable and technically feasible potential (ETP). The technical potential (TP) is based on the best available on the market at present.

### 5.10.1 TVs

There is currently a wide spread of efficiency on the market for the on-mode, with a ratio of more than 2:1 between the best and worst models for a given screen size. In 1988, the Lawrence Berkely Laboratory estimated that the average power demand of TVs currently on the US market could be reduced by 28% (US DOE 1993). The Rocky Mountains Institute estimated that this was still the case in 1990 and considered it to be a conservative estimate (RMI 1990). Sets on the 1994 EU market have a ratio of the average to the best 10% on the market of about 1.3. It is therefore assumed that a reduction of 30% on the current average is achievable by making the average attain the level of the 1994 best 10%.

Several technical options can be used to reduce standby in brown goods, all of which require changes to circuit design. For example, one of the major problems is that the same power supply is usually used for the standby circuitry and for operating the equipment. Each of these functions has different power demands. The supply is greatly over-rated for the standby mode and therefore operates less efficiently. A separate, purpose-designed supply could halve the standby power demand. The Finnish manufacturer Nokia is already selling some of their top of the range models with a standby consumption of 0.1W by radically redesigning the remote control circuitry. However, it is unlikely that such a level will be obtained as an average of the market unless prescriptive measures are used to control design techniques. A more realistic average is 1W, compared to the present 8W (Novem 1995).

### 5.10.2 VCRs

There is a wide spread in on-mode consumption on the current EU market, with an average of about 20W but with the average of the best 10% at 13W. 13W is therefore taken as the TP for the on-mode.

As for TVs, there is a very wide range of standby power demands on the market, from 4W to over 25W. Many of the TV design options can be used to reduce VCR standby, although it will always be higher than for TVs because of the clock circuitry. Research has shown that it would be possible to reduce it to 1W by implementing a number of changes, including using a liquid crystal display (LCD) instead of a fluorescent display, as LCDs use virtually no power. However, this would reduce visibility substantially and is probably an unrealistic option. A more likely figure is 2W, compared to the present 10W.

### 5.10.3 Satellite and cable

There is no data on the spread of the market or trends in the average over time, and it is therefore not possible to make any projections of TP for the on-mode. However, as for VCRs, the consumption is dominated by standby. There are few data on standby power for cable decoders, but there is a wide spread for satellite decoders, with individual appliances ranging from 4.5 to 35W. Many of the same technical solutions to TVs and VCRs  to lower standby would be applicable for these appliances, and a conservative TP figure of 4.5W as an average has been assumed based on the current best on the market.

### 5.10.4 Audio

Although in theory the on-mode power demand of audio equipment could be reduced by altering the design of the circuitry, there are no known examples on or near the market at the present time. There is therefore no projected change for the TP.

For the standby mode, the same TP figure of 2W as for VCRs is assumed as the selling price and technology are very similar.

## 5.11 POLICY OPTIONS

Figure 5.3 shows the electricity consumption under the BAU and the TP scenarios. Implementation of the TP scenario could result in annual electricity savings of 3.7TWh by 2020. A number of policy options could be used to access this potential. However, at present, there are no standard international or EU test procedures for measuring the electricity consumption of brown goods in either the on or standby modes, although there are no technical reasons why this cannot be done. The Swiss have drawn them up in conjunction with industry, and negotiations are under way between the EU and manufacturers.

As can be seen from Figures 5.1 and 5.2, the TV on-mode is the most important to target as it represents over 55% of the total for this group of appliances. For VCRs, satellite and cable, standby is the dominant mode and there is little point in targetting the on-mode as it is a small percentage of overall consumption.

**Table 5.3 Potential annual savings for the different brown goods by 2020**

| Appliance | Potential saving (TWh) |
|---|---|
| TV on-mode | 1.9 |
| TV standby | 0.47 |

| | |
|---|---|
| VCR standby | 0.52 |
| Sat/cable standby | 0.76 |
| Audio standby | 0.43 |
| TOTAL | 4.08 |

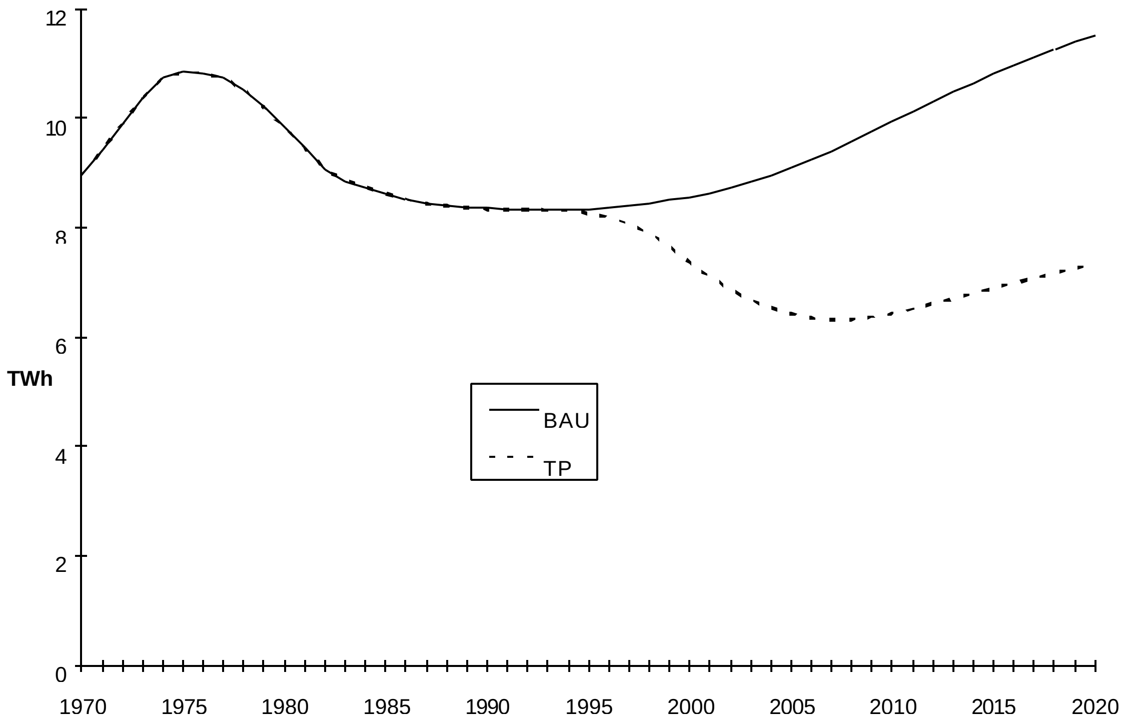


**Figure 5.3 A comparison of the BAU and TP scenarios for brown goods**

There are very few energy-related policy measures in place or planned for any of the brown goods anywhere in the world. The exceptions are Switzerland (voluntary targets for standby) and Sweden (procurement for TV standby). The Swiss scheme has already been outlined above. In Sweden, Nutek are preparing a standby procurement programme for TVs in hotels. Although hotel sales represent only a very small percentage of total sales (≈1%), the leverage on the total market could be substantial. Rapid technical and styling changes make brown goods different to, say, the cold and wet appliances. There is a large technical potential for efficiency improvements (which would be appropriate for energy labelling with other appliances), but the rapid rate of product change and the wide variety of features and different products on the market makes EU standard labelling of brown goods very problematic for the on-mode. Standby tends not to be affected by these factors. Award labels, such as the USA Energy Star system for office equipment, which are given to say the most efficient products on the market, and more effectively encourage ongoing technical innovation, may be more appropriate. However, all label schemes rely on the purchaser being concerned about energy consumption, yet there is no evidence that this is the case for brown goods. It may be that labels for standby will be more appropriate in the future when purchasers are used to regularly seeing them on other appliances and are aware of their significance.

A better approach is to set minimum standards or establish voluntary agreements with manufacturers as the Swiss Government has done. Standards offer good predictability of outcome. Although there is no way of knowing at this time if the first stage of the Swiss targets for TV standby will be complied with by January 1996, manufacturers have been cooperative in planning the implementation and providing the required data. Industry is now showing interest in implementing voluntary agreements at an EU level rather than minimum standards. As long as cooperation is forthcoming this is the preferable approach. However, if voluntary targets cannot deliver sufficient reductions over a fast enough time-scale, then minimum standards could be considered. A minimum standard or voluntary agreement implemented for VCR standby power in, say, 1998 would not be fully effective until 2014 as it would take 16 years for all the units sold prior to 1998 to leave the stock. It is therefore essential to act as soon as possible if the maximum benefit in terms of $CO_2$ emission reductions is to be attained.

However, voluntary targets currently proposed will not access the full technical potential by 2000. The agreements for TV and VCR standby would most likely be set at the Swiss level which is higher than the technical potential, and there are no agreements at present in place or being negotiated for the other types of equipment. Nor are there any policies in place for the on-mode consumption for any of the brown goods. Introducing the Swiss TV and VCR standby targets in the UK would result in a saving by 2000 of about 0.15TWh compared to the potential of about 1.2TWh. The full potential would only be achieved by the introduction of minimum standards for all the brown goods to be implemented by 2000.

Rebates are an effective way of encouraging purchase of the most efficient products and may also be more equitable as they enable lower income groups to obtain more efficient equipment which might normally be too expensive for their restricted budgets. It would be relatively easy to implement a scheme for standby, but more difficult for the TV on-mode due to the diversity of the market.

Procurement would be an appropriate policy for the on-mode for TVs to foster the introduction of LCDs or some other type of low energy display technology. This field is changing rapidly, largely driven by the development of low power demand screens for portable computers.

There is very little scope for changing usage patterns to lower the on-mode consumption for any of the brown goods as usage is a function of personal viewing and listening habits which are not readily changeable by policy, although healthy life-style campaigns could have some effect. This is also true for VCRs in standby because unless VCRs either automatically re-programme the clock (eg via teletext) or use a battery to power the clock circuitry, users will not unplug them from the mains. However, standby usage for TVs, satellite/cable and audio are highly dependent on behaviour because, as mentioned above, these are generally not performing any vital function in the standby mode. If users could be educated to turn them off, substantial savings could be made. This, however, requires raising consumer awareness of energy and that manufacturers provide a true off switch on the unit. A small number of households do unplug their VCRs when not at home or on holiday, but this is largely because of the fear of fire (as a result of a fire brigade warnings after a number of occurrences in early remote control TV sets) rather than due to a concern about energy.

Although the total potential electricity savings from standby are significant, it will be difficult to get households interested because the quantities of electricity involved for an individual appliance are small - it represents only a cost of a few pounds per annum for a VCR. It is therefore important that some form of user education is undertaken. Most people would be surprised to learn that their TV set could be consuming one quarter of the electricity in standby as when they are actually watching it. At present there is in reality little consumer choice over standby consumption. Apart from TVs, equipment is not designed to be readily disconnected from the electricity supply.

**Table 5.4 Summary of the effectiveness of policy options for brown goods**

| | TVs on | standby | VCRs standby | Sat/cable standby | Audio standby |
|---|---|---|---|---|---|
| Efficiency labels | | | | | |
| Award labels | | ▤ | ▤ | ▤ | ▤ |
| Minimum efficiency standards | | ▤▤ | ▤▤ | ▤▤ | ▤▤ |
| Voluntary agreements | | ▤▤▤ | ▤▤▤ | ▤▤▤ | ▤▤▤ |
| Rebates | ▤ | ▤▤ | ▤▤ | ▤▤ | ▤▤ |
| Procurement | ▤▤ | | | | |
| Other information | | ▤▤ | | ▤ | ▤ |

## 5.12 CONCLUSION

The brown goods are going to be a significant and rising component of domestic electricity consumption. Standby in particular requires attention as it is becoming an increasingly prevalent feature of power demand.

A similar package of policies would be appropriate for standby for all the brown goods. Industry is aready amenable to the idea of voluntary targets for standby, and this would be the best starting point. This could be run in conjunction with a rebate scheme for the most efficient products and an information campaign, perhaps leaflets at the point of sale, to educate purchasers about standby. After all, standby generally provides them with little if any extra service while costing them money.

The on-mode is only of real significance for TVs. This is a difficult area to address due to the changing features offered on the market. Manufacturers may view minimum standards as reducing their ability to introduce new features to make them more competitive. Once again, a voluntary agreement to reduce the sales weighted power demand might be appropriate. This could be similar to the USA CAFE system which would enable manufacturers to introduce new features that may increase power demand in some models as long as the overall market average was being reduced. At the same time a procurement programme for low power demand displays could be implemented which would assist in such a voluntary scheme by enabling the reduction of average power demand.

Reduced power demand will also help to extend the lifetime of brown goods due to less heat stress on components. This is an important factor, as brown goods, and electronic goods in general, are difficult to recycle for both technical and commercial reasons (Cooper 1994), and the large rise in the total number of sets has important implications for their disposal. At present, the average lifespan of TVs in the UK is estimated at 8.5 years. If this is not improved upon, by 2020 the UK will need to dispose of or recycle around 6 million sets pa. Durability is therefore an important element of policy. However, this is difficult to implement because of the rapid rate of change of the products themselves.

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## CHAPTER 6: COOKING APPLIANCES

### 6.1 INTRODUCTION

The major electric cooking appliances are hobs, ovens (including grills), kettles and microwaves, which together account for over 90% of all electricity consumption by cooking appliances. Other electric cooking appliances include a host of minor kitchen items such as toasters, coffee makers, deep fat fryers and food preparation devices.

Under the business-as-usual scenario, electricity consumption from cooking is projected to increase from 13.8 TWh in 1995 to 16.5 TWh in 2020. Cooking accounts for around 18% of total potential savings.

A number of trends need to be taken into account when analysing electricity consumption by cooking appliances. In addition to changes in ownership and efficiency, factors such as fuel switching (from gas to electric), and use changes (eg from grills to toasters, or from ovens to microwaves) have also been significant. Food habits have also changed over time: more meals are eaten outside the home and there has been an increase in popularity of convenience and pre-cooked foods. A further key element is changing household structure. There has been an increase in the percentage of one-person households, who tend to have a lower oven use.

## 6.2 Business-as-Usual (bau) SCENARIO

To date there has been no policy intervention in the UK to alter the technical characteristics of cooking appliances, or the way in which these are used. Ovens were included in the voluntary agreement in Germany in the early 1980s (Chapter 2), and were labelled in France and Denmark under the original voluntary EU labelling directive (79/530/EEC), though implementation and monitoring was poor. The business-as-usual scenario assumes that no policy intervention is applied to cooking appliances in the UK.

### 6.2.1 TOTAL ENERGY CONSUMPTION

Figure 6.1 illustrates the results of the electricity consumption modelling for all cooking appliances. The switch to gas in the late 1970s and early 1980s produced a short term decline in cooking electricity consumption. However, over the longer term reductions in average use per household and limited improvements in efficiency have been offset by an increasing number of households, and from 1985, a switch back to electric cookers and increasing ownership of other cooking appliances. The decline in consumption from ovens and hobs has been offset by increased consumption in kettles, microwaves and toasters. Electricity consumption from cooking is projected to increase from 13.8 TWh in 1995 to 16.5 TWh in 2020.

For cooking appliances, technical and usage time series have not been complete enough to develop a stock model as has been developed for the cold and wet appliances. For ovens, hobs, kettles and microwaves measured consumption (kWh pa where an appliance is present) by EA and LEEP has been relied upon for historic consumption. It has thus not been possible to show the relative importance of technical and behavioural factors in overall energy consumption. For the other cooking appliances, consumption has been estimated from technical and survey data.

Ownership, technical and usage trends are now examined.

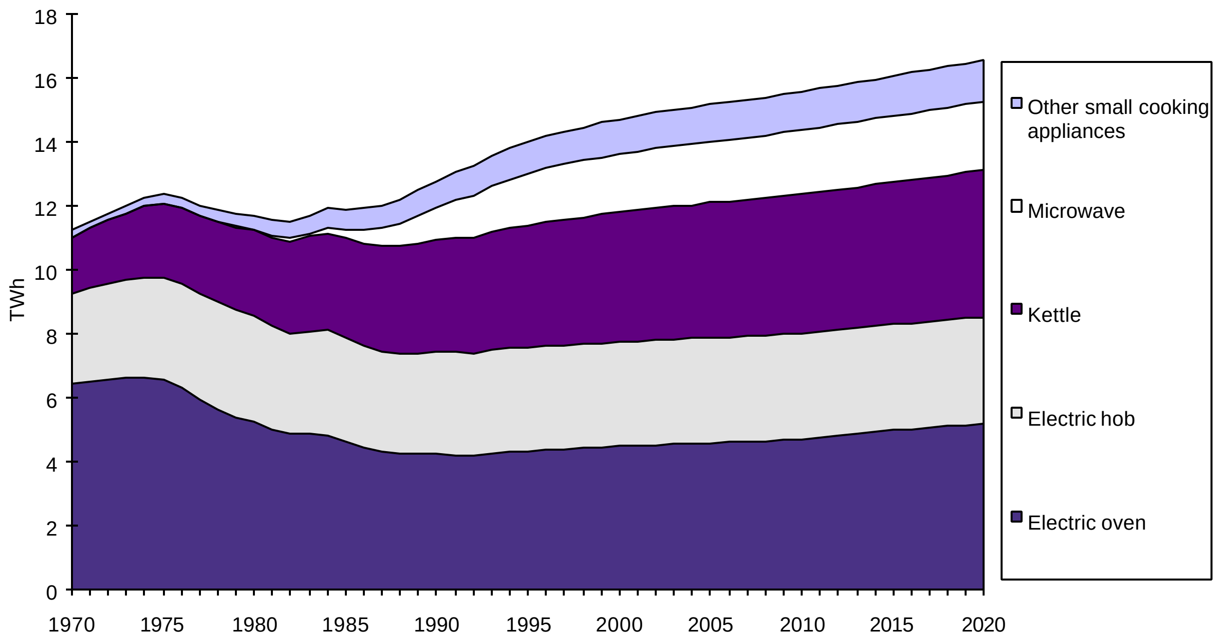


**Figure 6.1 UK electricity consumption by cooking appliances**

### 6.2.2 OWNERSHIP

Traditionally cookers were free-standing units that combined oven, hob and grill, but ownership of free-standing electric cookers has been in decline since 1979. As fitted kitchens became more popular, ovens and hobs could be separate appliances using different fuels. The electric oven/gas hob combination has increased from 1% of all households in 1979 to 9% in 1993 (GfK Home Audit). Over the same time period there has been an increase in ownership of electric ovens from 44% to 54% (GfK Home Audit). As a continuation of these trends, ownership of electric ovens is projected to increase to 69% in 2020, while ownership of all electric hobs is projected to decrease from 45% to 40%, as more households install fitted gas hobs.

Electric kettle ownership has grown from 59% in 1971 to 93% in 1992, and is likely to have displaced use of the hob, either gas or electric, for water heating. Ownership is projected to saturate at 95% by 2020. Microwave ownership grew from zero in 1976 to 63% in 1993. Ownership is projected to saturate at 75% by the year 2005. Ownership data on other small appliances has been taken from GfK Home Audit for historical data and projected forward to 2020.

### 6.2.3 TECHNICAL TRENDS

#### Ovens

Of the reductions in consumption recorded by EA, some of it may be due to technical improvements. There is no known time series on technical efficiency of ovens in the UK. However, ZVEI estimate that, between 1978-88 in the former West Germany, there was a 19% reduction in the energy used to heat ovens to 200°C and maintain that temperature for one hour. Analysis of current German manufacturers' catalogues shows that the current average is 1.1 kWh, and that there has been no improvement since the end of the voluntary agreement in 1988 (see Chapter 2). For the UK, ovens are assumed to have lagged the performance of those in Germany by five years (as has been found to be the case for cold and wet appliances). The business-as-usual scenario assumes no further improvement in efficiency in the absence of policy intervention (Figure 6.2).

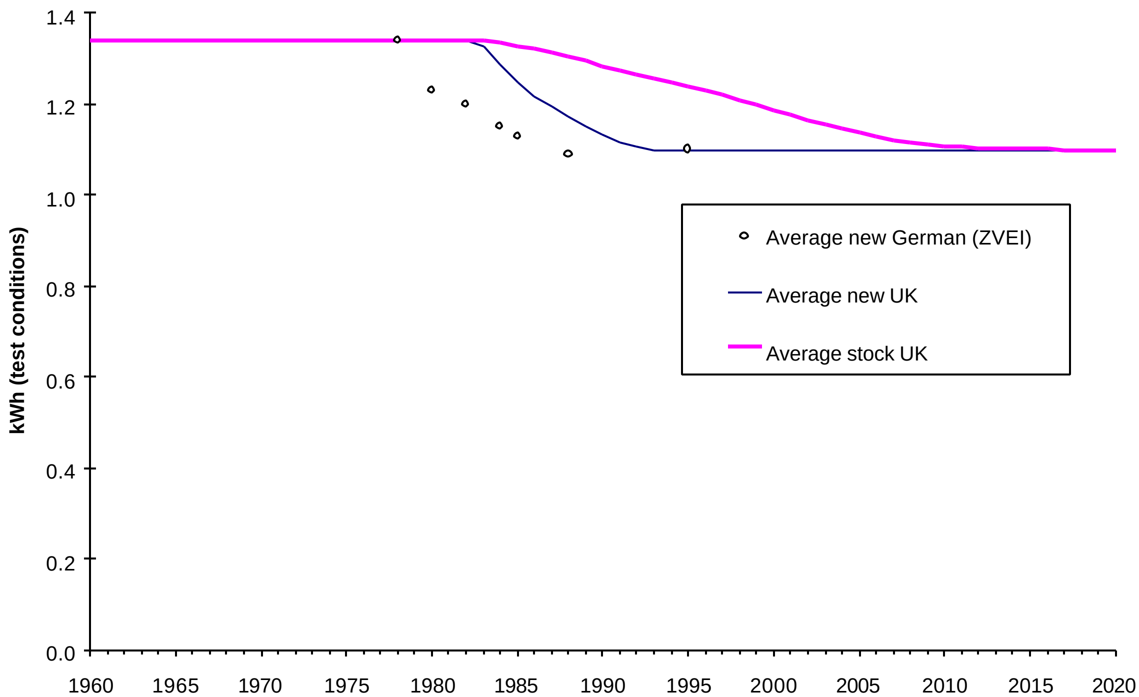


**Figure 6.2 Efficiency of the average new and stock oven in the UK**
(heating up to 200 C and maintaining for one hour)

Under test conditions (heating up to 200°C and maintaining that temperature for 1 hour) consumption by models on the current UK market varies from 0.8 to 1.9 kWh, a range of 1:2.4. The effect of volume seems minimal under test conditions. In practice, however, ovens are likely to consume more than this for the following reasons.

- the addition of food would increase the heat input required;
- door openings would increase heat loss;
- efficiency is likely to deteriorate through time as seals perish, while dirt on the inside of the oven increases radiative heat loss.

More measured data on oven electricity consumption in use is needed for a more comprehensive analysis.

**Hobs**

Hobs can be ring, solid plate, ceramic, halogen or induction. There is no known time series of hob efficiency. However, there is a relatively small range of efficiencies of hobs of a single technology on the market, and therefore hob efficiency is assumed not to have changed significantly over the time frame analysed. The range of efficiencies for some types of hobs is shown in Table 6.1. Under the business-as-usual scenario, no change in the efficiency of hob types is assumed.

**Table 6.1 Efficiency of different hob types**

| Hob type | Average delivered energy efficiency (%) | Average primary energy efficiency (%) |
|---|---|---|
| Solid disc | **41** | **12** |
| Ceramic | **48** | **14** |
| Halogen | **52** | **15** |
| Induction | **74** | **21** |
| Gas | **43** | **40** |

Source: RMI (1990:135)

### Kettles

There has been a switch to using electric instead of stove-top kettles in recent years, and also from conventional electric kettles to jug kettles. However, there is little difference in technical efficiency between jug and conventional kettles, and no improvement is assumed under the BAU scenario.

### Microwaves

There is little technical potential to improve the efficiency of microwave production. However, only part of total microwave consumption is due to cooking usage. For a microwave with an electronic timer, half of the consumption may be due to standby power for the clock display. The standby power demand is assumed to be similar to that of videos. Where a display is present therefore, standby consumption could be 61 kWh per annum. While standby power demand could decline from 7W to 1 W, the business-as-usual scenario assumes no improvement without policy intervention.

### Small cooking appliances

No improvement in efficiency is assumed for other appliances in the BAU scenario.

## 6.2.4 USAGE

Some of the reduction in consumption measured by EA may be due to a combination of social trends and changes in eating habits. Many of these cannot be quantified, and it has not been possible to develop a stock model for cooking which would require more data.

### Social trends

There are many separate social trends affecting cooking, but most of these cannot be quantified in energy terms.

- Demographic trends have conflicting impacts: an increasing number of households is tending to increase cooking energy use, but a higher percentage of one person households is to some extent offsetting this;
- The number of meals eaten at home has fallen, particularly as fewer households now eat at home at lunchtime because more women work outside the home;
- The types of food eaten have changed, with more convenience food that requires little or no cooking being used;
- As time devoted to cooking has decreased, greater use of convenience foods has been accompanied by increases in the use of labour-saving small appliances, such as food processors, and in faster cooking methods.

The increase in one person households is likely to have a major effect, as cooking electricity consumption is strongly influenced by household size. One person households in the LEEP sample consumed half of the average for two, three or four person households Figure 6.3). Part of the explanation is that oven use is thought to be very much lower in one person households (Wilson and Rees, *pers. comm.* 1995, and Arge Prüfgemeinschaft 1993). Future projections of oven and hob consumption has been adjusted to account for the increasing number of one person households.

The fall in electricity consumption from ovens and hobs per household (see below) may partly result from a decrease in the level of competence in cooking in the general population. Many people lack confidence in their ability to cook (Parkinson Cowan 1995) and this may lead to an increase in the use of meals which are to some extent pre-prepared.

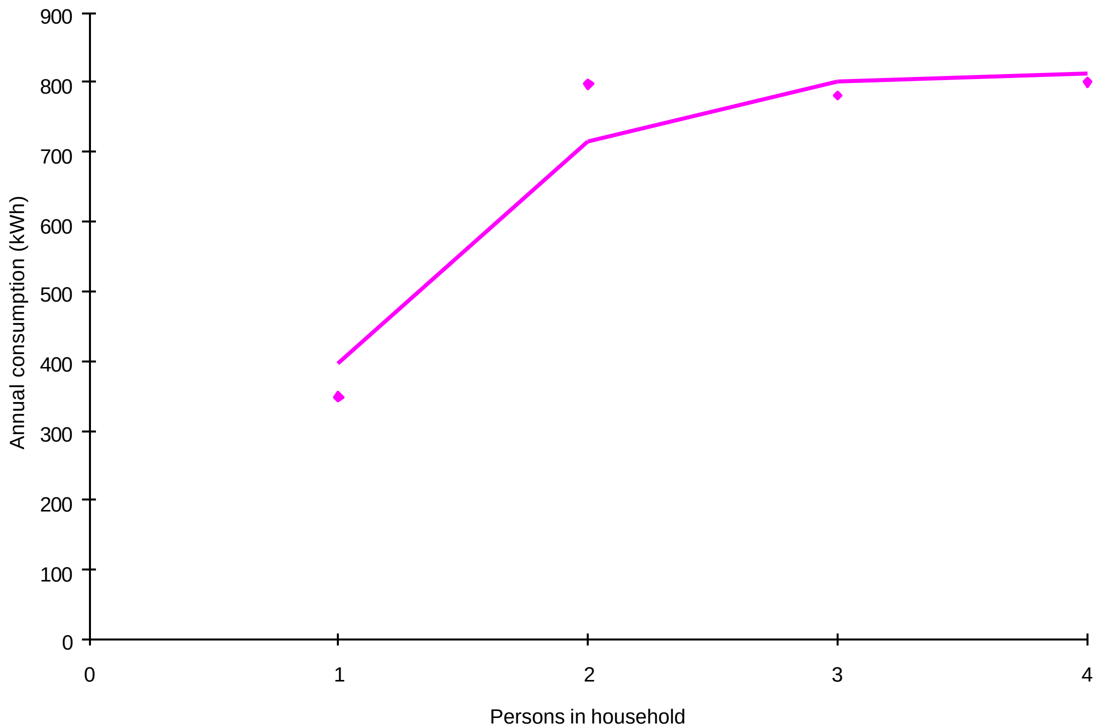


**Figure 6.3 Electric cooker consumption by household size (raw data and interpolated trend)**
Source: Analysis of LEEP data

The 1993 National Food Survey (MAFF 1994) included a special report on the use of convenience foods. This indicated that the amount the average household spends on convenience foods has risen from 25% of the total food bill in 1973 to 34% in 1993. The classification 'convenience food' covers a wide range of products, including canned foods, frozen ready meals, frozen vegetables, sausage rolls, crisps and breakfast cereals. Thus, increased use of convenience foods in general cannot readily be translated into changes in energy use in the domestic cooking process: increased use of breakfast cereals may decrease the use of the toaster, but a pre-cooked pizza still has to be heated in the oven.

**Ovens and hobs**

Electricity consumption of ovens and hobs has been measured in several surveys which have shown it to be falling over time:

- in 1982, cooker consumption varied from 910 kWh (freestanding) to 890 kWh (built-in) (Allera *pers. com.* 1994);
- in 1990, freestanding cooker consumption was 734 kWh, built in ovens were 429 kWh, and hobs 212 kWh (total built in 641 kWh), (ibid);
- in 1992, average consumption was measured at 640 kWh (ibid);
- in 1994, consumption measured by LEEP was 664 kWh. However the LEEP sample shows a range from 20 kWh to 1700 kWh.

EA estimated in 1990 that where both an electric hob are present, one third of cooker electricity use is from the hob, and two thirds from the oven. However, results from LEEP suggest that hob use is responsible for as much as 49% of total cooker electricity use. Thus it may be that households are moving away from oven cooking towards greater use of the hob. This is supported by qualitative and quantitative research (Parkinson Cowan 1995, Wilson and Rees *pers. comm* 1995.). It is assumed that the proportion of cooker electricity use attributable to hobs has increased from 33% to 49% over the period 1970 to 1992 where both hob and oven are electric. This split may be amended when additional data from the LEEP middle and high income groups becomes available. As ownership of electric ovens is higher than for electric hobs, ovens account for more than 51% of total oven and hob electricity consumption.

**Kettles**

Kettle use has been surveyed as being 22.3 uses per week per owning household, at 0.110 kWh per use, and therefore at 127.6 kWh pa (Wilson 1995). The LEEP figure was very much higher than this, (average use of 37 times per week) though LEEP households have a very high level of occupancy. For the model, an average of these two values was taken, giving an annual consumption of 169 kWh.

**Microwaves**

The advent of the microwave provided the possibility of some change in cooking methods. However, evidence on the impact of microwave ownership is not conclusive. A survey of households in Cardiff showed that the ownership of a microwave increased the amount of food cooked from raw, but decreased the energy required in food preparation (Burnett and Rees 1991). Households without a microwave had much higher oven consumption. However, more recent research suggests that microwave use is not displacing oven use, but is extra consumption, being used to cook vegetables, defrost frozen food and re-heat meals (Wilson 1995), although these activities could to some extent be displacing hob usage. The data from the Edinburgh sample (LEEP, 1995) demonstrate no statistically significant difference in cooker electricity consumption between households which own a microwave and those which do not. Thus it may be that, while microwave use once displaced oven use, this trend is no longer apparent. In any case it seems unlikely that future increases in ownership of microwaves will reduce oven consumption.

In the Cardiff study the number of uses of microwaves was measured at 10.6 per week (Wilson 1995). The average electricity consumption per use was 0.083 kWh, which gives a total of 45.7 kWh pa. Microwave consumption measured by EA appears to have increased from 50 kWh in 1982/3 to 94 kWh in 1989/90 (Allera *pers. com.* 1994). Much of the difference can be accounted for by standby consumption.

**Small cooking appliances**

The usage of small cooking appliances is infrequent. In a one-week diary of 106 homes in Cardiff, a deep fat fryer was used an average of 1.7 times by 10 households out of the 21 households that owned the appliance, thus average usage where a deep fat fryer was owned was 0.8 times per week. A slow cooker was used 0.166 times per week, a toaster 5.6 times per week, a coffee maker 0.92 times per week and a sandwich toaster 0.11 times per week. Consumption is less than 20 kWh pa for each of these appliances (based on Wilson 1995).

## 6.3 Technical Potential (TP)

Since almost all of the electricity used in cooking is to provide heat, most of the potential to improve energy consumption is, therefore, in reducing the thermal mass or reducing heat loss from cooking appliances.

However, for cooking appliances, it has not been possible to determine cost effectiveness in the same way as for cold, wet and lighting appliances. In particular, an analysis of the cost of each design option plus the cumulative effect in energy savings (eg as used by GEA) has not been attempted: thus analysis is based on proven and commercially available technologies rather than a cost benefit calculation.

The technical potential (TP) is a 42% improvement for ovens and a 66% improvement in hob efficiency. March estimated a 55% improvement in electric cooker consumption (March Consulting 1990: E16), though they appear to have assumed a much higher basecase energy consumption.

The total TP saves some 7.5 TWh. This represents 18% of the total ETP savings from all domestic appliances. Of the 7.5 TWh, most comes from ovens (40%), hobs (27%), kettles (12%), microwaves (15%), and only 5% from small appliances (Table 6.2).

**Table 6.2 UK cooking consumption (GWh)**

| | Oven | Hob | Kettle | Micro-wave | Total small | Total cooking |
|---|---|---|---|---|---|---|
| 1995 | 4312 | 3239 | 3826 | 1609 | 981 | 15962 |
| 2020 BAU | 5166 | 3320 | 4594 | 2139 | 1418 | 16637 |
| 2020 TP | 2179 | 1286 | 3676 | 1027 | 1004 | 9172 |

### 6.3.1 Ovens

Substantial electricity savings are available. If all appliances sold were as efficient as the best on the market (and the average moved from 1.10 to 0.8 kWh to heat up to 200°C and maintain for one hour), the energy saving would be some 27%. There are many ways to improve the thermal performance of ovens:

- reducing the thermal mass of the oven,
- reducing radiative heat loss,

- changing the insulant to a lower thermal conductivity or increasing insulation thickness,
- improving heat transfer within the oven from element to food, by increasing air movement using a fan. Heat transfer can be improved by a factor of four (Franks *pers. comm.* 1995). Fan assisted ovens have a reduced warm up time (from 25 minutes to 15 minutes), and can cook at reduced temperatures or for reduced times. The net effect is an improvement of 16-25%,
- reducing the number of air changes per hour (Doubling the air changes per hour decreased oven efficiency by 11%), and
- improved door seals.

The net effect could be a 42% improvement in efficiency (Farah 1993, SAI 1977, RMI 1990). This does not represent the technical limit to efficiency, but that accessible at limited cost. One prototype design fits inside a conventional oven, and uses 0.15 kWh to reach 200C and 0.14 kWh to maintain, reducing consumption to 26% of current average (Norgard 1989). In addition to these options, vacuum panels which are so cost effective for refrigeration can retain performance characteristics at high temperature, which makes then an option for ovens, water heaters and small cooking appliances (Waide and Herring 1993:64).

### 6.3.2 Hobs

The most significant, technically proven electricity-saving option for hobs is a switch in technology to induction hob cooking. However induction hobs are expensive, currently over £1000, or more than 7-8 times more than a solid plate hob, and three times more than halogen designs. However, this cost is thought to be due to the low market penetration and perceived luxury value of the product rather than to a genuine difference in manufacturing costs. Assuming higher penetration and more conventional mark-ups, paybacks are assumed to be economic, and the ETP scenario assumes 100% penetration of induction hobs where electricity remains the choice fuel. However, induction hobs still have only half the system efficiency of cooking with gas hobs, and fuel switching to gas where possible would provide $CO_2$ reduction together with significant cost savings.

The efficiency of cooking in the home, rather than under test conditions, varies widely. A pot with a warped bottom reduces heat flows and increases the required cooking energy by half. Thus actual efficiency can be improved by

- reducing the thermal mass of the hob,
- improving hob to pan contact,
- increasing the absorption of radiative heat by having a dark exterior,
- reducing radiative heat loss by having a reflective interior.

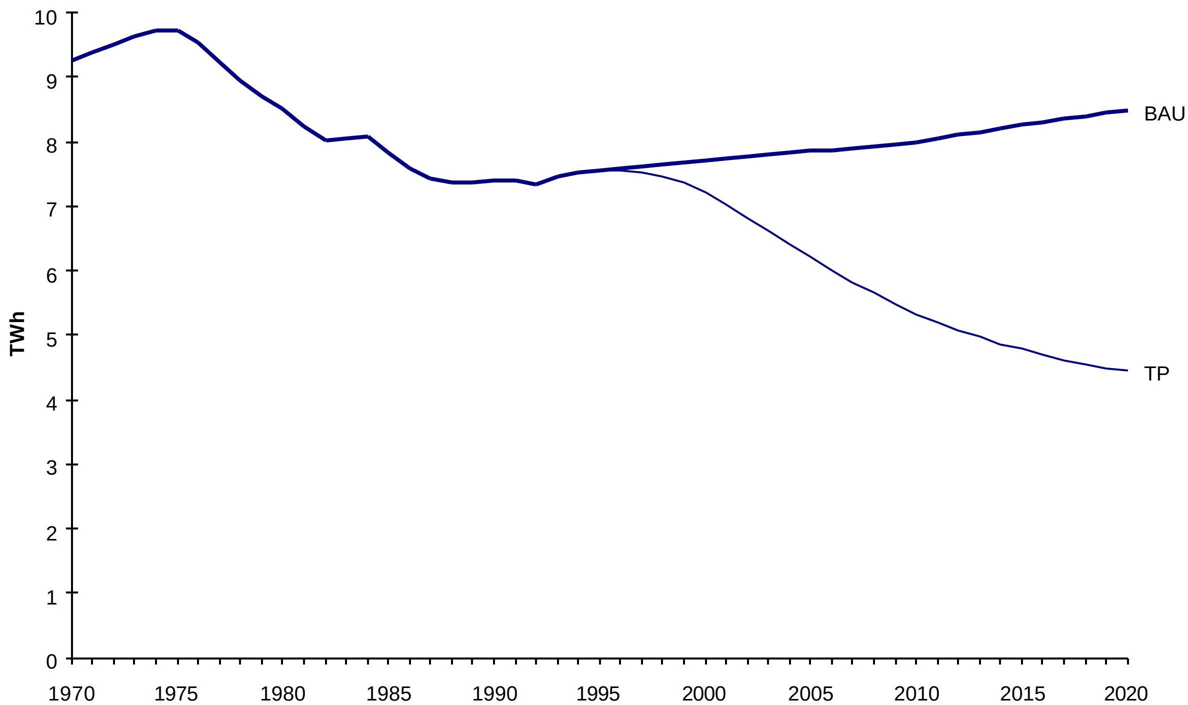


**Figure 6.4 BAU and TP for UK electric cookers (hobs and ovens)**

### 6.3.3 Kettles, microwaves and small cooking appliances

While at present there is little variation in energy efficiencies among these appliances on the current market, there is considerable potential for improvement. Up to half of users boil a kettle and then walk away, returning sometime later and reboiling it before using the water. This wasted energy would be greatly reduced by a double skinned kettle designed to reduce heat loss, a design for which is about to be launched on the Australian market. Energy savings are expected to be around 20% (Sweatman *pers. comm*. 1995). A kettle over its 5 year lifetime consumes 845 kWh, worth £54 discounted at 8%. A 20% saving is worth £10.80 over its life, justifying an increased purchase price.

Standby consumption of microwaves could be reduced to levels similar to those proposed for TVs and videos (see Chapter 5). The heat loss of small cooking appliances such as deep fat fryers and slow cookers could be reduced by 40% through improved insulation, similar to that for cookers and cold appliances.

## 6.4 Policy options to Access potential SAVINGS

The issues which are key to a discussion of policy initiatives were raised in Section 2.3, and have been discussed in this chapter with reference to cooking. In summary:

- a test protocol exists for ovens and could be developed for hobs and other devices;
- there is a wide range of efficiencies of ovens on the market at present, but little variation in hobs of the same technology;
- consumer awareness of energy issues at the point of sale of cooking devices remains low,
- there is a great deal of potential improvement in ovens by combining the best known design options, and by bringing new technologies to market;

- oven technology has been relatively stable, while hob technology has seen recent innovation; and
- there is substantial variation in cooking consumption from behavioural differences, and little awareness of the importance of certain actions.

### 6.4.1 Policy aimed at technical improvement

There was some technical improvement in German ovens due to the voluntary agreement referred to above, but this seems to have slowed in recent years. There is some variation in efficiency on the current market and considerable potential for further improvement, including vacuum panels. The market share of efficient ovens could be improved with labelling. Technology procurement could bring together all of the design options to reduce oven consumption into one model to demonstrate the economically justified technical potential, and give a good indication of costs and drawbacks of design options, including vacuum panels. Labels and procurement could be used as the basis for efficiency standards for ovens by 2000. A switch to induction hobs would need to be focussed on incentives to reduce initial cost, perhaps through rebates or differential levels of VAT. The physical condition of cooking equipment is also an important factor. A pot with a warped base, and therefore poor thermal contact with the hob, can increase the electricity consumed by 50%. Warping is only a significant factor with heat transfer between two supposedly adjacent surfaces, and not with gas or with induction hobs.

### 6.4.2 Policy aimed at changing usage

Behaviour has a great influence on cooking energy consumption and there is a large potential to reduce it through education and information campaigns. One survey showed a variation of 50% between people cooking identical meals using the same cooking equipment (Bagshaw 1981). This can be due to a number of factors such as:

- most people do not know how long their oven takes to heat up, and ovens are often turned on much earlier than is necessary for preheating (Wilson and Rees *pers comm* 1995);
- incorrect sizing of pots;
- leaving the lids off pans on the hob can result in using 3 to 5 times the required energy (RMI 1990:135, Brundrett and Poultney 1979);
- many people overfill their kettles – one survey found that 27% of people always filled their kettle completely, regardless of the amount of hot water they actually required (Nicholls and Rees 1983).
- the automatic kettle has also resulted in many people re-boiling the kettle after it has switched off – a recent survey in Australia found that over half of people do this (Sweatman *pers. comm*. 1995).

The avoidance of electric oven usage through switching to microwave ovens also has the potential to greatly reduce cooking energy usage. As mentioned in section 6.2.4, there is some evidence that many households only use their microwaves to defrost and re-heat food rather than for cooking it completely. Microwaves are much more efficient than normal ovens at putting heat into food and they use much less energy for a given cooking task, and therefore produce much less $CO_2$ as a result. To put 1 kWh of heat energy into a given quantity of food, on average an electric oven will result in the emission of 13 kg of $CO_2$, a gas oven about 3 kg and a microwave only 1 kg.

There is obviously scope for an information campaign to raise awareness of these issues. However, many people do not respond well to being ‘told how to cook’ and the design of such a programme may be very difficult, as will assessing the energy savings from such programmes.

## 6.5 Conclusions

There are clear uncertainties involved in modelling both historic and projected electricity consumption for cooking: a full stock model has not been possible because of the lack of time series behavioural and technical data, the variations in test procedures for measuring hob efficiency, and many social trends that are difficult to quantify. Thus it has not been possible to rank the relative importance of factors behind the measured decline in electricity consumption per household. However, factors include:

- increases in one person households;
- gas ovens displaced with electric fitted ovens where gas is not a preferred fuel;
- increased ownership of electric kettles, toasters and microwaves displacing hob or grill use which may have been of either fuel;
- and changes in eating habits.

Technical improvements have been historically less important. The analysis shows the importance of grouping appliances by function: consideration of free-standing cookers or ovens in isolation would give a false impression. It has not been possible to perform a full cost benefit analysis of hobs and ovens with the resources and data available, and the improvements identified are more of an easily accessible technical potential rather than a full ETP.

Given these caveats, under the business-as-usual scenario, total cooking electricity consumption is projected to increase from 15.9 TWh in 1995 to 16.6 TWh by 2020. The technical potential is a 42% improvement for ovens and a 66% improvement in hob efficiency. The total technical potential from cooking saves some 7.5 TWh or 18% of the total ETP savings from appliances.

Policy initiatives could focus on stimulating new markets for efficient ovens and kettles, and for induction hobs, while efficiency standards may have a secondary role in improving ovens. There is a considerable potential for improving energy efficiency from education.

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# CHAPTER 7: LIGHTING

Jane Palmer

## 7.1 INTRODUCTION

This chapter covers domestic lighting, concentrating on light bulbs rather than light fittings. Domestic lighting electricity consumption in the UK may be far higher than previously thought, in some cases double previous figures. This has implications for estimates of domestic electricity consumption in other areas, such as space and water heating, which would need to be reduced in order to accommodate the higher lighting consumption within total household electricity bills. Possible reasons for previous underestimates of the electricity use from lighting include the lack of measured data on lighting electricity consumption and the fact that studies have concentrated on the lighting circuit, so the lights connected to the ring main, such as table lamps, have often been overlooked.

DECADE estimates that, in 1994, lighting accounted for 24% of domestic appliance and lighting electricity consumption and thus represents an area with significant energy saving potential. The revised figures have been generated through a lighting stock model, based on sales data, taking into account the measured and survey data available. However, the data available on lighting are very limited, presenting problems when modelling lighting electricity consumption. It is surprising that so little is known in areas such as lighting usage and ownership of light bulbs and fittings considering lighting is present in every household and uses a high proportion of electricity. In the future, it is likely that data will become more readily available through increased monitoring of schemes and through greater interest in the market for energy-efficient light bulbs. The DECADE lighting consumption calculation, which forms the basis of this chapter, has been constructed to ensure that such data will be easy to incorporate.

## 7.2 TYPES OF DOMESTIC LIGHT BULBS

An energy efficient light bulb is one with a high efficacy, where efficacy is the total light output of the light source divided by the total power input. There is a large range in the efficiencies of light bulbs currently available on the UK market, the least efficient of which are the standard incandescent light bulbs (also known as the general lighting service (GLS) light bulb). Low voltage tungsten halogen bulbs (20W - 50W) are similar to incandescent bulbs in that both use tungsten filaments, and they are also relatively inefficient. Although tungsten halogen bulbs have a higher efficacy than incandescents, the halogen bulbs suffer transformer losses and there is often a trade off of lifetime against efficiency. Hence many of the available tungsten halogen bulbs are not necessarily more efficient than incandescents but simply have longer lifetimes. The high wattage halogen lamps used for external security purposes have not been included here, but are discussed in section 7.3.3. Among the more efficient bulbs are the fluorescent strip lights and the compact fluorescent light bulbs (CFLs), which can be up to 4-5 times more efficient than incandescents. The overall efficiency of fluorescent lights will vary depending upon the type of ballast they use; electronic ballasts are gradually replacing the less efficient magnetic ballasts. Electronic ballasts also have the advantages of reducing general flicker and switching the light on instantaneously, which increases the lifetime of the bulb. CFL ballasts also vary as to whether they are an integral or external part of the bulb. External ballasts have several advantages over integral ballasts:

- there is less wastage, since only the bulb and not the ballast, is discarded at the end of the bulb's life. The ballast itself will last for about 4 bulbs,
- the cost of replacement CFLs for an external ballast is far lower than the cost of integral ballast CFLs,

- there is less risk of reversion to incandescents with external ballasts since the light fitting can only take CFLs. This is highlighted in a recent report from Sweden, where only 60% of contacted customers replaced burned out CFLs with another CFL (Mills 1995).

### 7.3 BUSINESS-AS-USUAL (BAU) SCENARIO

The business-as-usual (BAU) scenario in Figure 7.1 shows a sharp increase in historical consumption from 9.1 TWh in 1970 to 17.3 TWh in 1990. After 1990 the increase in consumption is less marked. This is partly due to the introduction of CFLs onto the market and partly due to a shift from 100W bulbs to 60W bulbs. The shift reflects a change in the type of fittings in a household from single source ceiling

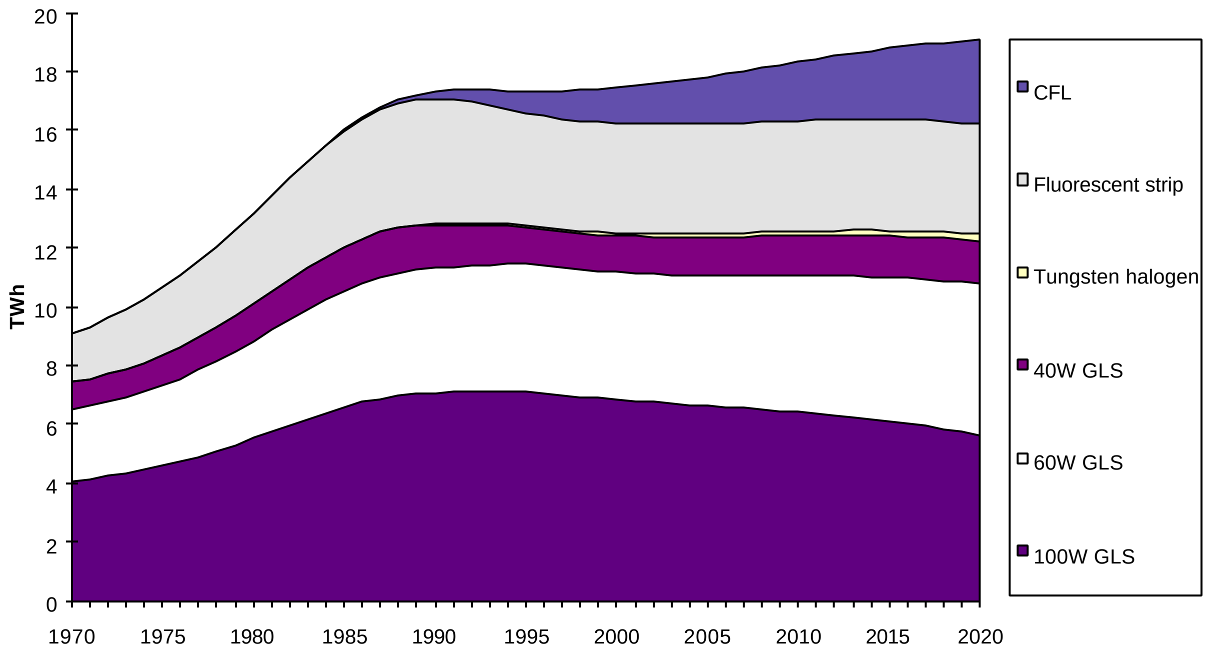


**Figure 7.1 UK total annual domestic lighting electricity consumption, 1970-2020**

lights to multi-source, indirect and task lighting located mainly in wall and table lamps. CFLs are expected to replace incandescents, to represent 40% of the total number of light bulbs in an average household by 2020. Lighting electricity consumption is projected to increase to 19.1 TWh by the year 2020, mainly due to an increase in both the number of households and the number of light fittings per household.

#### 7.3.1 Ownership

Ownership data for light bulbs do not exist at present. It has not been possible to identify the average number of light bulbs per household over time since such data have not been recorded. However, from available sales data, it is apparent that the incandescent light bulb is still the main source of light in the majority of UK households. Table 7.1 provides a breakdown of sales between the main classes of light bulbs in 1990 and 1992.

**Table 7.1 UK sales of domestic light bulbs by bulb type, 1990 and 1992**

| Bulb Type | 1990 (%) | 1992 (%) |
|---|---|---|
| GLS bulbs | 92.2 | 92.7 |
| Tungsten halogen bulbs | 0.5 | 0.5 |
| Fluorescent strip lighting | 5.2 | 4.2 |
| Compact fluorescent lights | 2.1 | 2.6 |
| **Total sales** | **191 million** | **191 million** |

Source: MINTEL (1993)

The sales data have been put through a stock model to generate historic and present day ownership figures for domestic lighting, giving a calculated increase in the average number of light bulbs per household from 12 in 1970 to 17 in 1990. It is possible that these estimated figures may be slightly high since retail sales of domestic light bulbs may not all go to the domestic sector. However, the 1994 AMA Research report on the UK Lighting Market estimates an average of 18 bulbs per household, which is consistent with the DECADE figures.

Since sales figures are inherently unpredictable, the projections of the model are based upon expected ownership rather than sales. The average number of bulbs per household is assumed to increase as a result of the current market trend of increased sales of task lighting, multi-socket luminaires (light fittings), and outdoor/security fittings. There is also a growing trend towards increasing CFL ownership. Current sales figures indicate that, of the total number of bulbs in the average household in 1994, almost 80% are incandescents and just 9% are CFLs. In other words, out of the 17 bulbs per household, just over 13 of these will be incandescents and about 1.5 bulbs will be CFLs. However, these figures are for the *average* household. At present, the percentage of UK households that actually own a CFL is only about 16%. In the business-as-usual scenario the total number of bulbs, and the corresponding split between the various bulb types, are projected into the future (Figure 7.2). The proportion of CFLs in stock is based on an assumption that 20% of total light bulb sales in 2020 will be CFLs. These projections suggest 46% of total light burning hours will be due to CFLs by the year 2020.

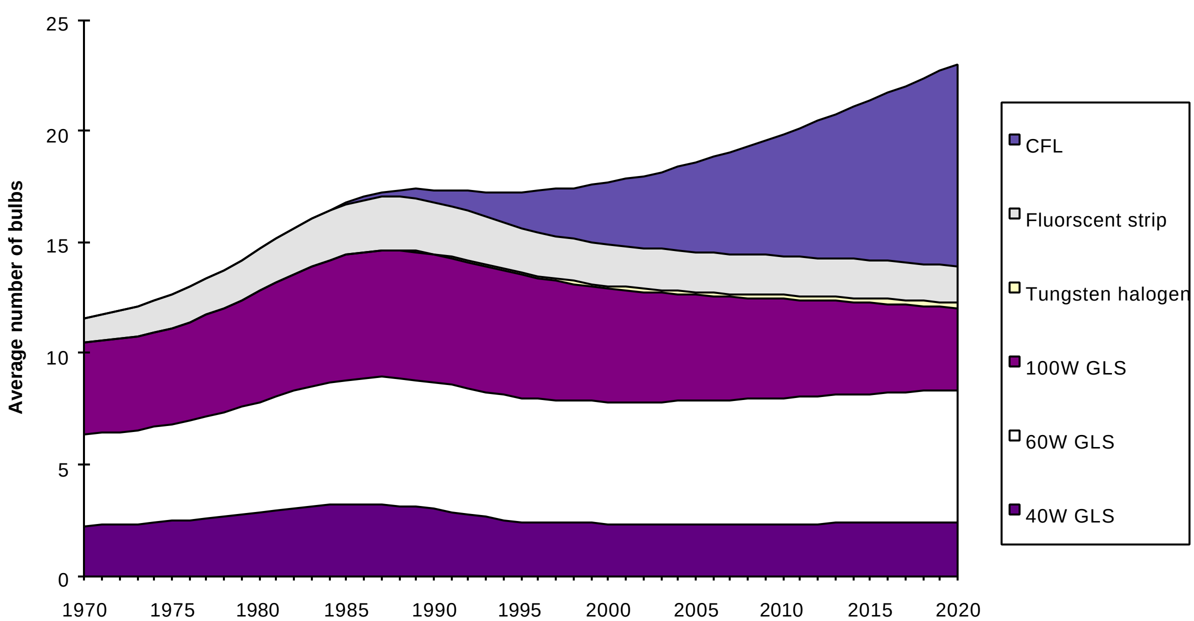

**Figure 7.2 Average number of light bulbs per UK household, BAU**

### 7.3.2 Background policies assumed

Under the Standards of Performance (SoP) programme, the twelve regional electricity companies (RECs) in England and Wales are required by the regulator to spend £100 million on reducing electricity demand between 1994 and 1998. Many of the early initiatives have included low energy lighting; two schemes funded by the RECs and run by the Energy Saving Trust have targeted ownership of low energy light bulbs in the UK domestic sector:

- A national campaign to increase sales of CFLs by reducing their retail price by £5 through subsidies to the manufacturers. This type of project has been run annually since 1993 with successive improvements each year, such as only subsidising electronic ballast CFLs and including small independent retailers in the scheme.
- The Home Energy Efficiency Scheme provides basic insulation and energy advice free to people on means tested benefit or over 60 years of age. In 1994, this scheme was extended so that recipients of energy advice also received two low-energy light bulbs. A total of 430,000 free CFLs were distributed in this way.

The number of CFLs distributed through these two schemes totalled almost 1.5 million in 1994. Evaluation of the programmes found that public awareness of CFLs had increased from 58% to 72% of all households, although people are still relatively unaware of the actual savings that can be achieved over the lifetime of a CFL. The increase in CFL sales through the subsidy programme is thought to have been stimulated by the lower price. However, it was considered that, for additional stimulation of sales, a further 50% reduction in the price of CFLs would be required, with prices in between having little impact. Future EST schemes are likely to be targeted towards cheaper, smaller CFLs, with greater light output (Heywood and Rowbury 1995).

### 7.3.3 Trends in usage patterns

This is another area in which data for domestic lighting are limited. The only measured electricity consumption in lighting comes from a study done in Birmingham in 1982 (EIK) and from the study being undertaken by the Lothian and Edinburgh Environmental Partnership (LEEP). The EIK study was in local authority housing and the present LEEP data are from low-income households. Neither sample can be considered to be more widely representative.

Although the lighting circuit and ring circuit were both covered in the initial LEEP questionnaire of low-income households, only the lighting circuit (ceiling and wall lamps) was actually metered. Thus table lamps and other light fittings on the ring circuit were not included in the metering. For an accurate measurement of household lighting electricity consumption, both the lighting circuit and the ring circuit need to be metered. An estimate for the ring circuit can be made based on the questionnaires, but comparison of the reported and measured data for the lighting circuit showed that the estimates by the householders were inaccurate. This highlights the need for actual metering of lighting usage, rather than using surveys and diaries. Such data should be forthcoming as a result of an Electricity Association project, to be undertaken in 1996, which is funded by the EU SAVE programme. The DECADE team will be collaborating with the Electricity Association on this project.

An estimate for total lighting electricity consumption of the low-income households was made by multiplying the metered consumption to reflect the apparent balance (63% : 37%) between usage on the lighting circuit and ring circuit (Stenberg 1995). This is a particularly uncertain ratio, although it was also assumed in extrapolation of the data from the EIK study, which, like LEEP, had only metered the consumption on the lighting circuit.

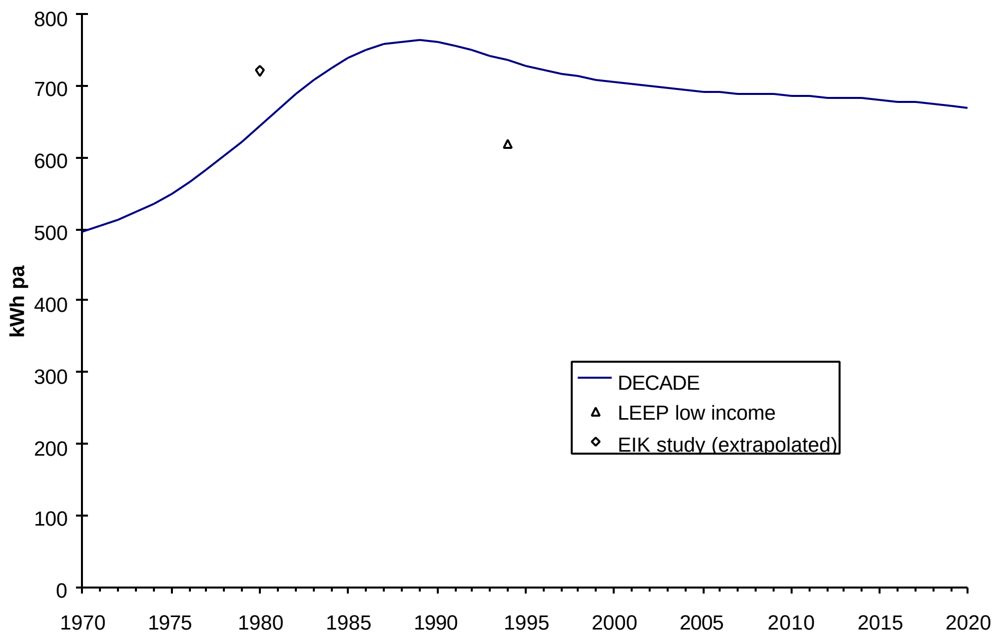


**Figure 7.3 Lighting electricity consumption per household, UK, 1970-2020**

The projection in Figure 7.3 shows a decrease in lighting consumption per household from 1988, which is primarily due to the replacement of incandescents with CFLs. However, preliminary analysis of the initial questionnaire from the LEEP middle income group estimates lighting consumption per household at 890 kWh pa in 1995, far higher than the DECADE figures. Studies in other countries have also found lighting electricity consumption to be higher than previously estimated. For instance, the Technical University of Denmark measured lighting electricity consumption in 100 houses and found an average of 900 kWh pa per household (Thomsen 1994).

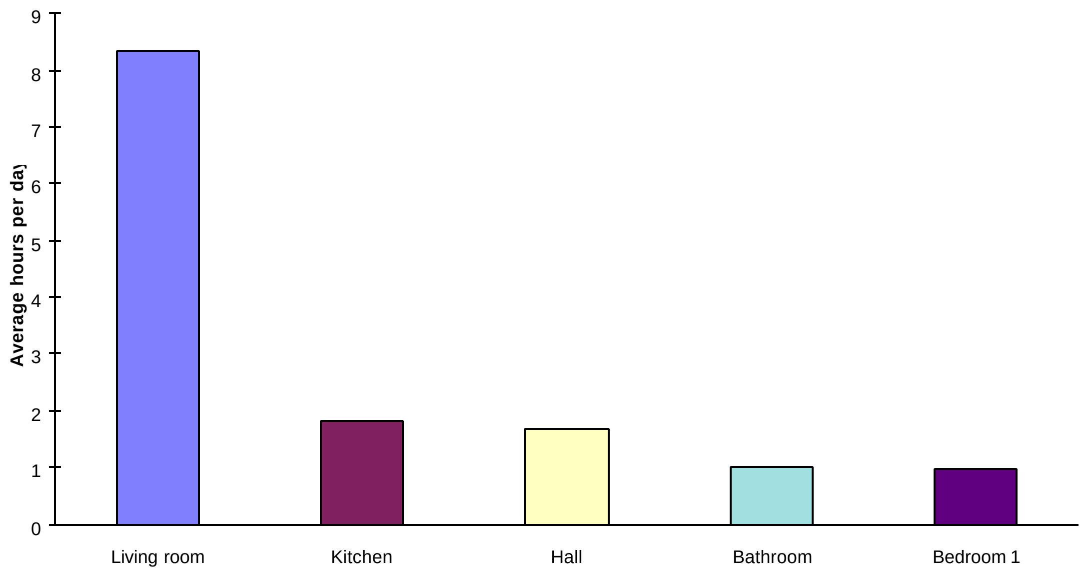


**Figure 7.4 LEEP low-income questionnaire estimates of average daily hours of lighting in various locations (ring circuit and lighting circuit combined)**

Analysis of the LEEP surveyed data for the low-income group has shown that a high percentage of usage is concentrated in very few lamps, with almost 50% estimated to be on the living room ring and lighting circuit. It should be remembered that these are estimated figures for low-income households which are likely to be smaller houses with fewer light bulbs per household. However, this concentration in usage distribution is supported by other studies (eg Mills *et al* 1995) and implies that a significant reduction in lighting electricity consumption could be achieved by replacing only a small number of incandescent light bulbs with CFLs in the high use sockets in each household.

There has been a growing trend towards outdoor security lighting over the past few years, with the installation of powerful halogen light bulbs (150W - 200W) controlled by automatic sensors. This type of external lighting has not, as yet, been included in the DECADE calculations due to the lack of data. More information is needed since it is an area of rapid growth and high electricity consumption. Another aspect of the increase in concern for security is the habit of leaving internal lights on to imply occupancy. The extent to which this occurs is not known at present and is another area which would require measurement of lighting usage in order to identify exact levels of electricity consumption.

Concern has been expressed over the relatively high levels of toxic heavy metals in CFLs compared with incandescent bulbs. This is less of a problem if the bulbs are disposed of properly and for those CFLs which use an external ballast. Also, the reduction in pollution from power stations consequent upon the decreased electricity demand resulting from replacing incandescents with CFLs, far outweighs the increased pollution from CFL disposal (Gydesen and Maimann 1991). Coal burning power stations actually produce large amounts of heavy metals in the process of generating electricity, equivalent to far higher levels of toxic waste than result from the disposal of CFLs.

### 7.3.4 Total energy consumption

The DECADE lighting electricity consumption figures take into account the average lifetime of the bulb in hours, the average wattage of the bulb and the service life of the bulb in years, all of which may change through time. For example, as the number of CFLs increases, it has been assumed that there will be a corresponding increase in the service life of CFLs (ie the number of years a CFL remains in use). This is because CFLs will start to occupy lower use sockets, consequently the average CFL lifetime of 8000 hours will be spread over a greater number of years. The same can be said for the incandescent bulbs as they are displaced by CFLs to low-use sockets such as cupboards.

The increase in the service life of light bulbs has the effect of slowing down the projected rate of increase in the volume of total light bulb sales, from an average annual increase of 3.2% between 1970 and 1994 to 0.7% between 1994 and 2020. However, sales are still expected to increase overall, mainly due to the increase in both the number of households and the number of light fittings per household.

## 7.4 ECONOMIC AND TECHNICAL POTENTIAL (ETP) SCENARIO

Domestic lighting economic and technical potential (ETP) is based upon a life cycle cost analysis, taking into consideration the initial purchase price and the lifetime running costs of CFLs relative to incandescents. Such analysis estimates that, in purely economic terms, it is worthwhile placing a CFL, with an integral, electronic ballast, in any fitting used for more than 250 hours a year. This assumes an 8% rate of return, electricity costing 7.5p per kWh, incandescent bulbs costing £0.75 and has been calculated for a range of current CFL prices (Table 7.2). The 11W and 20W CFLs are equivalent to 60W and 100W incandescent bulbs respectively.

**Table 7.2 Pay back periods, in years, for the replacement of 60W and 100W incandescent bulbs with CFLs, at two usage levels**

| | **60 Watt** | | **100 Watt** | |
|---|---|---|---|---|
| **Cost of CFL replacement** | 250 hours/year | 365 hours/year | 250 hours/year | 365 hours/year |
| £5 (11W) | 6 | 5 | 4 | 3 |
| £6.50 (20W) | 10 | 6 | 5 | 4 |
| £9.50 (20W) | 17 | 9 | 8 | 5 |

Source: DECADE estimates

This results in a pay back period for the CFLs of between 3-17 years, depending on the wattage of the bulb being replaced and the annual usage of the fitting in which the replacement is made. From analysis of the LEEP low-income questionnaire data, fittings in the average household estimated to be in use for over 250 hours per year represent 84% of total burning hours. Hence it is economically justified, ignoring the cost of altering existing fittings, for sales of CFLs to increase to almost 50% and fluorescent strip sales to decrease to 1% of total sales by the year 2000. However, the pay back periods are very sensitive to changes in the purchase price of CFLs. The current trend is towards a decrease in price which will reduce pay back periods, thus increasing the potential savings.

The ETP gives an overall reduction in total lighting electricity consumption of 61% by 2000 compared with the business-as-usual scenario. This decrease is similar to that measured in a Danish study which found a 60% electricity saving after conventional bulbs had been replaced with the best-available CFLs (Thomsen 1994). Previous estimates for the UK, using existing CFL technology, suggested 75% potential savings (Eyre 1990). In the USA, as a result of the implementation of various policies and improved CFL design, the sales of CFLs as a percentage of the total bulb market has increased from 4% to 9% between 1992 and 1995. Hence, the substantial savings identified by the ETP scenario are plausible within the criteria used.

This ETP is based purely on economic rather than technical potential, and aims to give an indication of the level of savings which could be achieved. However, there are several factors which have not yet been accounted for in the ETP scenario:

- CFLs with external electronic ballasts, which are cheaper in terms of replacement bulbs (as opposed to initial cost), are not considered,
- take back, where people are inclined to leave lights on for longer if they are perceived as being cheaper to run, is not included,
- many fittings are not suitable for CFLs and so there is the further cost of replacing such fittings,

assuming an average lifetime of 8000 hours, a CFL which is only used for 250 hours per year will potentially last for up to 32 years. The likelihood of this occurring in practice will depend upon several

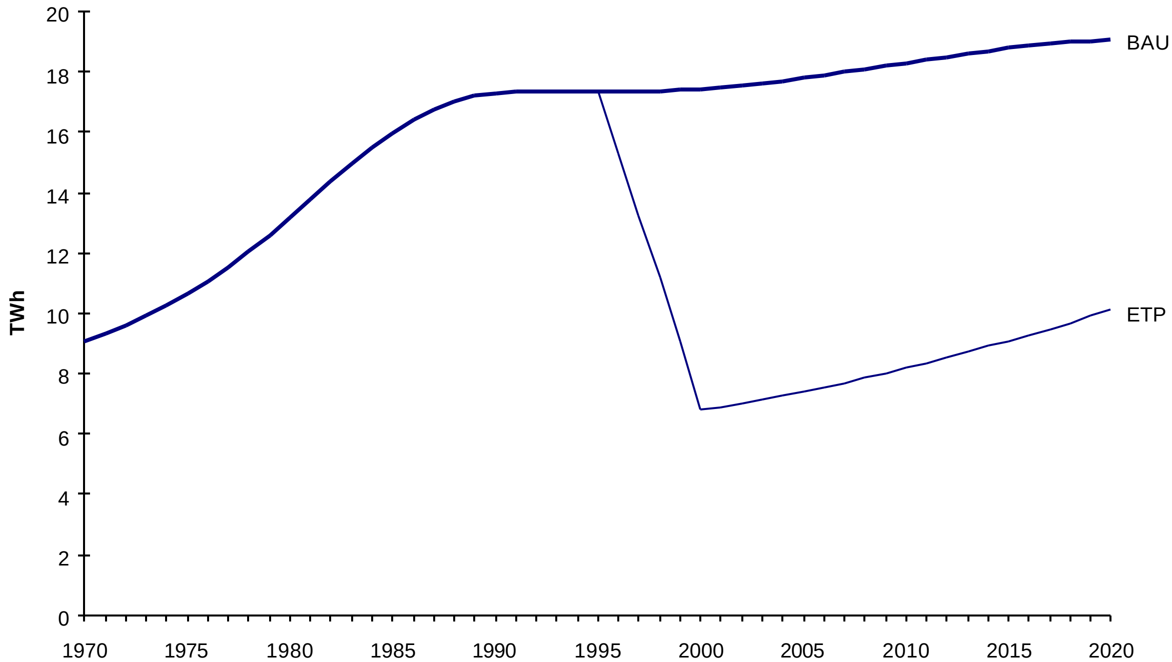


**Figure 7.5 BAU and ETP domestic lighting electricity consumption, UK, 1970-2020**

aspects of household behaviour which are difficult to predict, such as tolerance of light fittings which last so long, frequency of redecoration, and breakages when moving house.

### 7.5 POLICY OPTIONS

Domestic lighting is an area with a wide spread of efficiencies on the market and a large technical potential. Consumer understanding of energy saving potential from lighting is increasing rapidly. In order to access the ETP, there needs to be a switch in sales from incandescents to CFLs, with an emphasis on CFLs using external electronic ballasts. Lighting technology has become more dynamic in recent years including development of electronic and separate ballast units. Since incandescent light bulbs have such a short life span relative to other domestic appliances, the implementation of any policy will have a relatively rapid effect.

#### 7.5.1 Information

Light usage patterns show a wide variation, but there is scope to improve efficiency in high use fittings. Consumer education could focus attention in the most used areas.

In the past, shape, size, brightness, flicker, slow start, colour and weight as elements that have restricted uptake of CFLs (EEO 1994). Manufacturers have tackled many of these problems, but consumer understanding of these changes is relatively low.

Energy labelling would assist in educating the public and raising general awareness of the efficiency of different classes of bulbs. There is already a draft EU directive regarding energy labelling of household lamps, which is likely to come into force by the end of 1996. Similar labels can already be found on cold appliances and will also be on wet appliances by 1996 and so should already be familiar to some consumers. The proposed label includes details on the energy efficiency class of the lamp ranging from

A-E, the light output of the lamp in Lumens, the power consumption of the lamp in Watts and the life of the bulb in hours, unless this information is included elsewhere on the packaging. The label is not permitted to be smaller than 40% of the standard size laid down in the directive giving minimum dimensions of 19mm by 33mm.

### 7.5.2 Economic Incentives

The key barrier to increased penetration of CFLs is the cost relative to incandescents. Cost is an area being targeted by the EST with subsidy schemes. Other policies aiming to increase the market share of CFLs could help: differential rates of value added tax for lamps could be especially effective.

Procurement programmes for light fittings specifically designed to take CFLs could help ensure a high market share for the more efficient technologies, and encourage replacement with a CFL once the original lamp burns out.

### 7.5.3 Regulation

Minimum product standards, or linking lighting to building standards, could eliminate magnetic ballasts in favour of more efficienct electronic ballasts, and favour external ballast units as opposed to integral ballasts.

## 7.6 CONCLUSION

Domestic lighting electricity consumption is likely to be far higher than previously thought, consuming 17.4 TWh in 1994. The increase suggested is consistent with measurements of lighting consumption in other countries. Improved data collection and monitoring, with actual measurements of lighting consumption on both the ring and lighting circuits, are important in verifying calculations. The Electricity Association/SAVE light monitoring programme will go some way towards achieving this.

Lighting is an area of great energy saving potential, with a possible annual electricty saving of 9 TWh by 2020, which could be accessed through appropriate policies. A primary aim could be to increase CFL ownership to a level where the high use fittings in all households contain CFLs. Again, it is essential that more data are made available to enable detailed evaluation of the various policy options.

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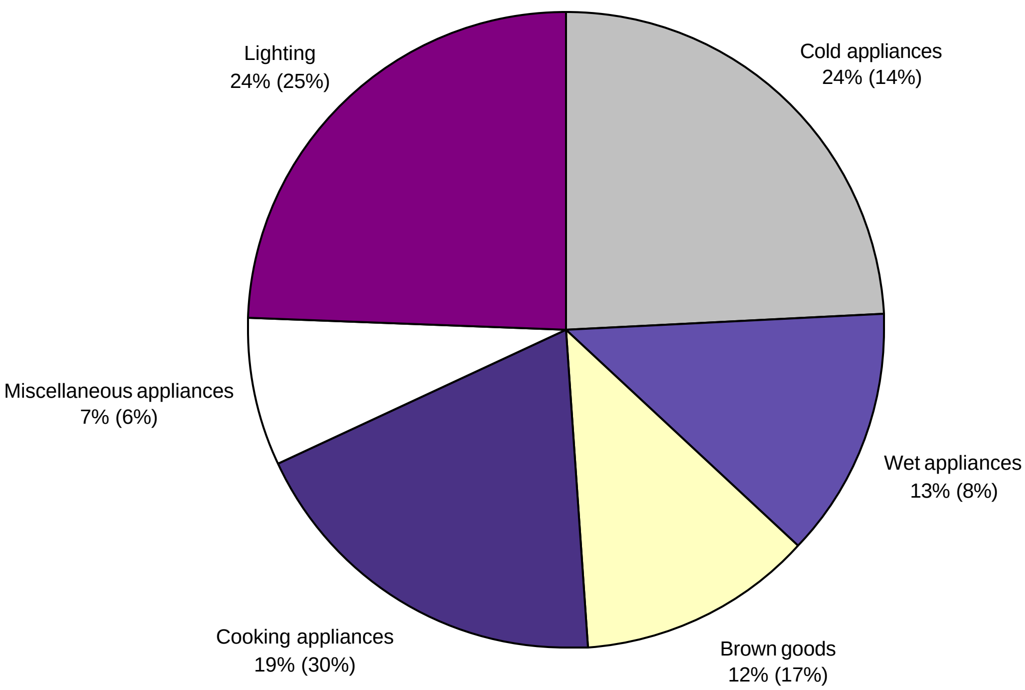
## CHAPTER 8: ELECTRICITY CONSUMPTION IN LIGHTING AND APPLIANCES

KEVIN LANE
JANE PALMER

### 8.1 INTRODUCTION

The last five chapters have presented detailed analyses of cold, wet, brown and cooking appliance groups and lighting. These five major categories, together with the minor appliances, comprise the total electricity consumption in appliances and lighting. The DECADE model includes in lights and appliances all those uses of electricity that are not covered by space and water heating, by the Building Research Establishment. This is to ensure that there is complete coverage between the two models of all UK domestic electricity consumption.

The minor appliances represented 6% of all electricity consumption in lights and appliances in 1970 and by 1994 this had grown to 7% (Figure 8.1). The proportion of total electricity consumption in lights and appliances taken up by the main categories of appliances has changed considerably in the last 25 years with, for example, a sizeable decrease in consumption for cooking and a considerable increase in that of the cold appliances.




**Error! Switch argument not specified.Figure 8.1 Electricity consumption by appliance group in 1994 (1970 in brackets)**

This chapter has two aims: first, it outlines consumption from these minor appliances and then, more importantly, it draws together total consumption from all appliances under the business-as-usual (BAU) and economic and technical potential (ETP) scenarios. The potential savings are analysed by appliance group in terms of electricity consumption, consumer expenditure and $CO_2$ emissions.

## 8.2 MINOR APPLIANCES

The detailed approach undertaken by the DECADE project has enabled the minor appliances to be dealt with in considerable detail rather than be grouped together in a ‘miscellaneous’ or ‘other’ category. This is an important improvement on other models as it reduces unexplained consumption. The DECADE model identifies 15 categories (Appendix C) and each of these has been modelled separately.

Of the minor appliances those that account for significant consumption are identified in Figure 8.2. The ‘other’ appliances represent aspects of homecare, DIY, gardening and home office equipment. These minor appliances, in total, cover all the remaining uses of electricity in the home, except for space and water heating. Two substantial uses - electricity for central heating pumps and electric showers - are included for completeness with BRE.

The minor appliances have been dealt with in similar detail to the major appliances in the model. However, the lack of time series data on their efficiency means that it has not been possible to develop a stock model, with some minimal loss in accuracy and modelling capability. Usage data for these minor appliances is in short supply, but assumptions have been made about the interactions between societal trends and the implications for individual appliance ownership. An example is electric blankets: while ownership is levelling off, use has been falling due to rising ownership of central heating and higher average indoor winter temperatures.

The minor appliances account for 5.4 TWh consumption in 1994 and this is projected to rise to 9.1 TWh by 2020. The main users of electricity in this category in 1995 are electric showers followed by central heating pumps, irons and vacuum cleaners. By 2020, personal computers are projected to become the fourth largest user in this group displacing vacuum cleaners. Public perception about the relative consumption of different appliances is unreliable and usually related to factors such as the operating noise. Therefore, vacuum cleaners are thought to be heavy users of electricity, whereas they only consume around 0.5 TWh, which is for example, a quarter of microwave consumption.

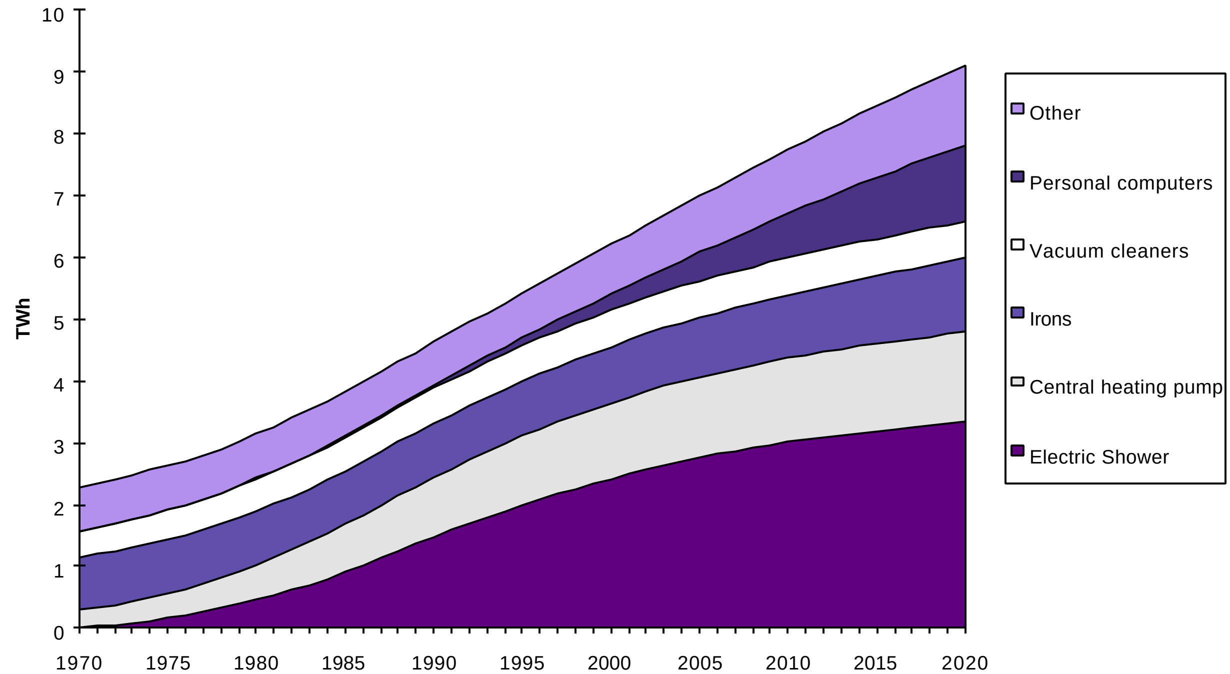



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**Figure 8.2. Electricity consumption in the minor appliances, UK 1970-2020**

Four major trends within the minor appliance group have been identified and are projected into the future:

- rising levels of gas central heating and hot water systems has increased electricity use in the pumps required to circulate the hot water. The rise in central heating has reduced the use of electric blankets and electrically-heated towel rails, as indoor temperatures increase. Ownership of electric showers is still growing independently of central heating and gas water heating;
- more homes have items that have previously been seen as office equipment: computers, answering machines and faxes. Both ownership and use of these are increasing and the latter two will consume electricity in standby modes;
- ownership of gardening, DIY and homecare appliances is increasing, but the usage of individual appliances may fall. For instance, ownership of an electric sander does not necessarily indicate increased DIY activity, it may imply increasing specialisation of tools by displacing use of a power drill;
- irons, vacuum cleaners and hairdryers have seen a small increase in the wattage of the average new appliance, but a slight decline in usage.

Due to the diversity of products and lack of data an ETP scenario has not been calculated for these appliances: for the minor appliances, the BAU and the ETP are exactly the same. There are cost-effective opportunities for electricity consumption to be reduced, but the model has not been extended to this level of detail. For instance, shower consumption could be reduced through fuel switching from electricity to gas (resulting in both financial and $CO_2$ emissions savings). Another example is that standby consumption from information technology appliances could be reduced significantly as a side effect of policy intervention aimed primarily at commercial office equipment.

## 8.3 SUMMARY OF BAU SCENARIO FOR DOMESTIC LIGHTS AND APPLIANCES

The aggregate effect of the BAU scenarios from each of the major appliance categories and the minor appliances is described. The baseline projections have been built up from trends in ownership, technology and usage.

### 8.3.1 Ownership, technical and usage trends

As described earlier, much of the increase in consumption is driven by rising household numbers. The DECADE team has taken a cautious approach in making the BAU projections. As the graph demonstrates, the present level of ownership is, in most cases, assumed to change little (Figure 8.3). Ownership levels of home computers, dishwashers and tumble dryers are still expected to rise. Multiple ownership of TVs and videos coupled with increased levels of lighting in the home have all contributed to greater electricity consumption and will drive further increases.

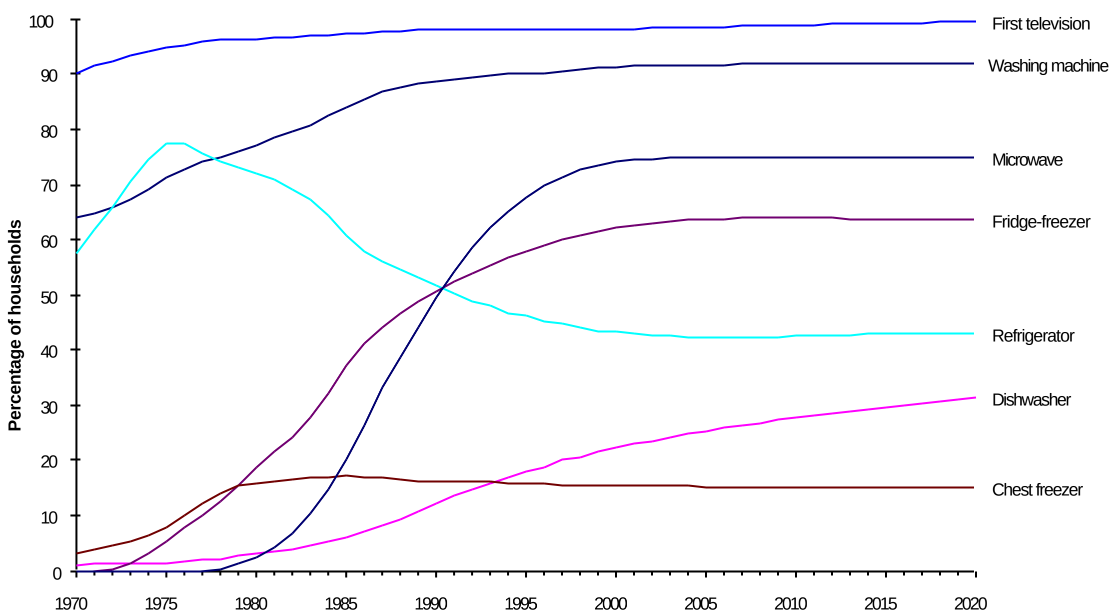


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**Figure 8.3 Ownership of various household domestic appliances, UK 1970-2020**

Most appliances have become more efficient over the last 25 years, as explained in Chapter 3-7. However, the improved technology has been offset by a general trend towards increased usage in this period. The additional usage results from two general trends: first, improved standards of living and, secondly, consumers tend to take back a proportion of efficiency improvements through a higher level of service. For example, energy efficient light bulbs may be left switched on for longer purely because they are more efficient.

One of the social and behavioural trends is that there appears to be an increasingly independent use of space and services, with individual members of the household occupying separate rooms, rather than undertaking family activities. For example, teenagers have TVs or home computers (and presumably lighting and heating) in their own rooms. This trend may be one of the reasons why reducing household size has not always led to a lower household consumption. For instance, in 1970 the average household was 2.9 people and electricity consumption for lights and appliances was 2000 kWh pa (or 690 kWh per person). By 1994, the size of the average household had dropped to 2.5 people and yet consumption had risen to 3000 kWh pa (1,200 kWh per person). As this higher level of electricity is being used with more efficient appliances, the increase in consumption represents a substantial improvement in the standard of energy services obtained.

The DECADE projections indicate that household energy consumption will level off into the future, but because the household size is still declining, the level of energy services per person will continue to rise.

The electricity consumption in the five major groups and the minor appliances is summed through time to give the BAU scenario shown in Figure 8.4. As stated in Chapter 1, the electricity consumed in this sector represent 24% of all the electricity used in the UK in 1994. By 2020, the projected consumption is more than double (at 83 TWh) that occurring in 1970. This continuing predicted growth is in contrast to the projection of flat demand from the Department of Trade and Industry.

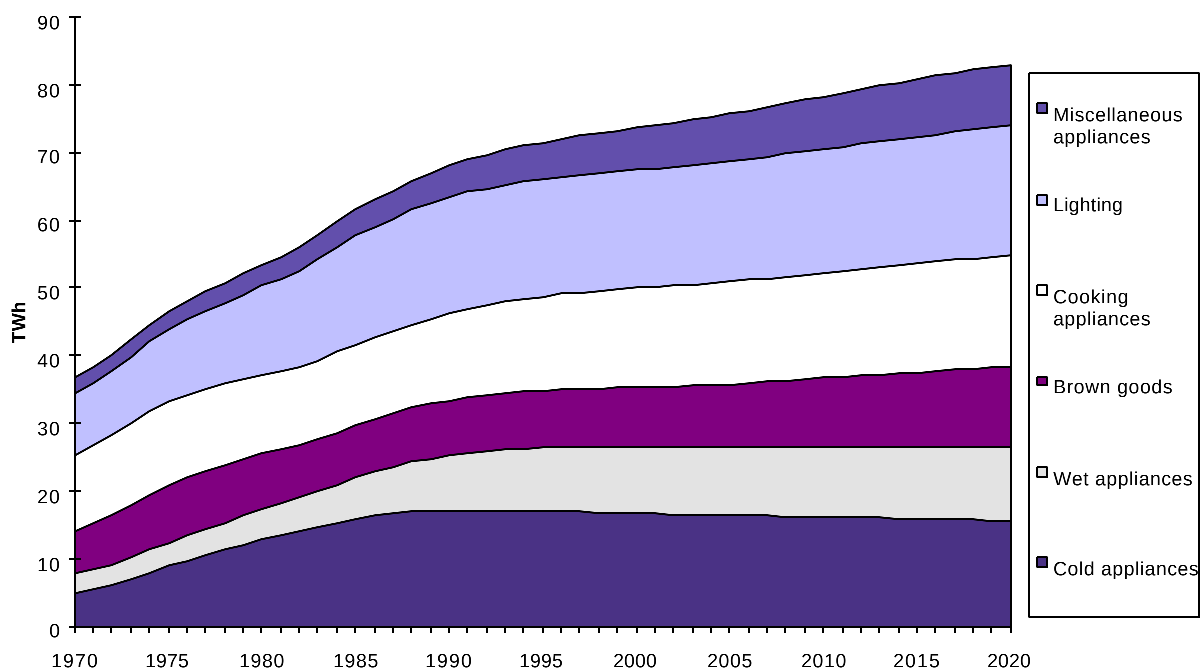


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**Figure 8.4. Electricity consumption in domestic lights and appliances, BAU scenario, UK 1970-2020**

Under the BAU, the minor appliances show the largest percentage increase (Table 8.1), partly because of the difficulties of tracking technology change in this range and number of appliances. This probable underestimate of energy efficiency improvements for the known minor appliances may offset electricity consumption by new appliances, yet to come onto the market. The only group where consumption is projected to decline is cold appliances, where historic improvements in consumption are expected to be reinforced by energy labelling and minimum efficiency standards, and should counteract the effect of increased households and ownership. In absolute terms, the most growth will be in electricity consumption in lighting. The main trends are increases in both the number of light bulbs per house and the number of hours the lights are on. The introduction of CFLs will circumvent some of this increase.

Consumption from brown goods will increase with many homes owning additional televisions and a second video, together with increased standby consumption from satellite and cable provision. Cooking appliance electricity consumption remains fairly constant into the future.

**Table 8.1 Summary of UK BAU scenario**

| | BAU 1994 (TWh) | BAU 2020 (TWh) | Change (TWh) | Change (%) |
|---|---|---|---|---|
| Cold | 17.1 | 15.6 | -1.5 | -8.5 |
| Wet | 9.3 | 11.0 | 1.7 | 18.5 |
| Brown | 8.3 | 11.7 | 3.4 | 40.9 |
| Cooking | 13.8 | 16.5 | 2.8 | 20.0 |
| Lighting | 17.3 | 19.1 | 1.8 | 10.0 |
| Miscellaneous | 5.3 | 9.1 | 3.8 | 72.8 |
| Total | 71.0 | 83.0 | 12.0 | 16.9 |

**8.4 SUMMARY OF ETP SCENARIO FOR LIGHTS AND APPLIANCES**

The economic and technical potential has been summed (Figure 8.5). With brown and cooking appliances the economic analysis was limited, so the projection for these two groups is more correctly of the technical potential (see respective chapters). With this caveat, the ETP is treated here as if it were a consistent approach. If all the ETP were realised for all the major appliances then electricity consumption could be reduced to 51 TWh, a saving of 32 TWh equivalent to 39% of projected consumption by domestic appliances and lighting in 2020.

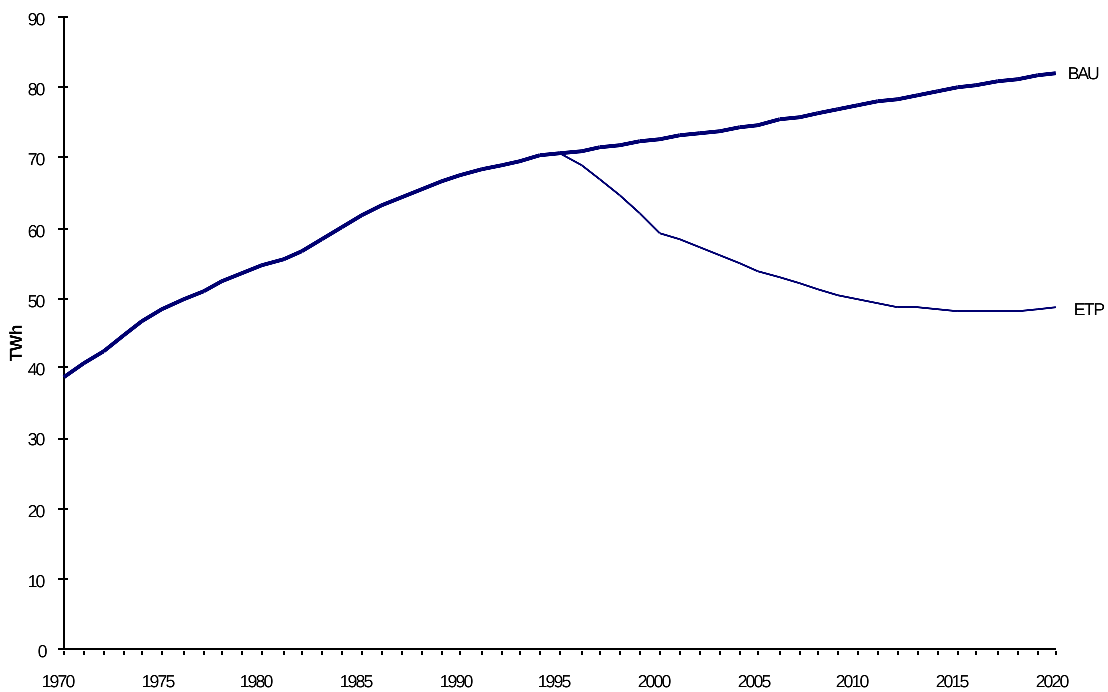


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**Figure 8.5 The BAU and ETP scenarios for UK domestic appliance and lighting consumption**

The savings identified under the ETP scenario are 'potential'. There are policies that would access this potential, as discussed in the relevant chapters, but there is no suggestion that these policies would be able to achieve all the savings, especially in the short term.

Potential savings are not available equally from all appliance groups, nor at the same rate. In 2000, two-thirds of the total potential savings could come from lighting. This is because the replacement time of bulbs is shorter than any of the appliances, so more of the stock of equipment has already achieved the new, higher levels of energy efficiency that would have been promoted by policy intervention. By 2020, lighting and cold appliances account for 60% of all ETP savings. The potential savings and associated time delays can be seen in Figure 8.6.

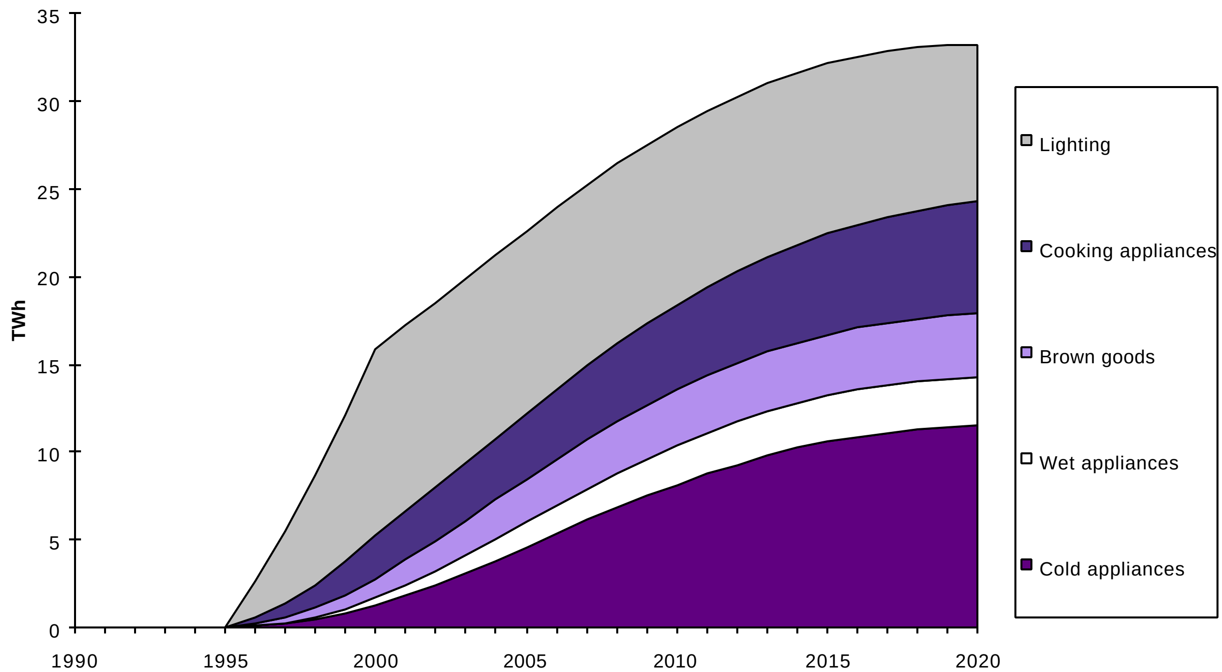


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**Figure 8.6 Economic and technical savings potential by appliance group, UK 1995-2020**

Due to the impossibility of predicting feasible technology at viable prices more than five years ahead, no further development in the ETP is assumed from 2000 onwards. The only exception to this is vacuum panels for cold appliances which are assumed not to be ready for 100% market penetration until 2005. While the technical ETP is introduced by 2000 for average new appliances, the effect of such programmes will not be felt fully until all the appliances are replaced in the stock, which, depending on the appliance, might not be until 2020. This ETP scenario does not represent the technical limit and further savings may become cost effective if equipment prices decrease or energy prices increase.

Historical and projected changes in the fuel mix for electricity generation have been taken into account. A factor for converting electricity consumption to carbon dioxide (kg$CO_2$/kWh) is given in Appendix A for each year, as this is changing as the fuel generating mix varies. The switch from coal to gas-fired generating capacity and the increase in supply from nuclear power stations during the 1990s has meant emissions from domestic appliances and lighting have fallen dramatically and will continue to decline until 2000 (Figure 8.7). With no further policy intervention, emissions will then rise steadily back to 1990 levels. In order to restrain emissions at around the 2000 level, some or all of the identified ETP savings would need to be accessed.

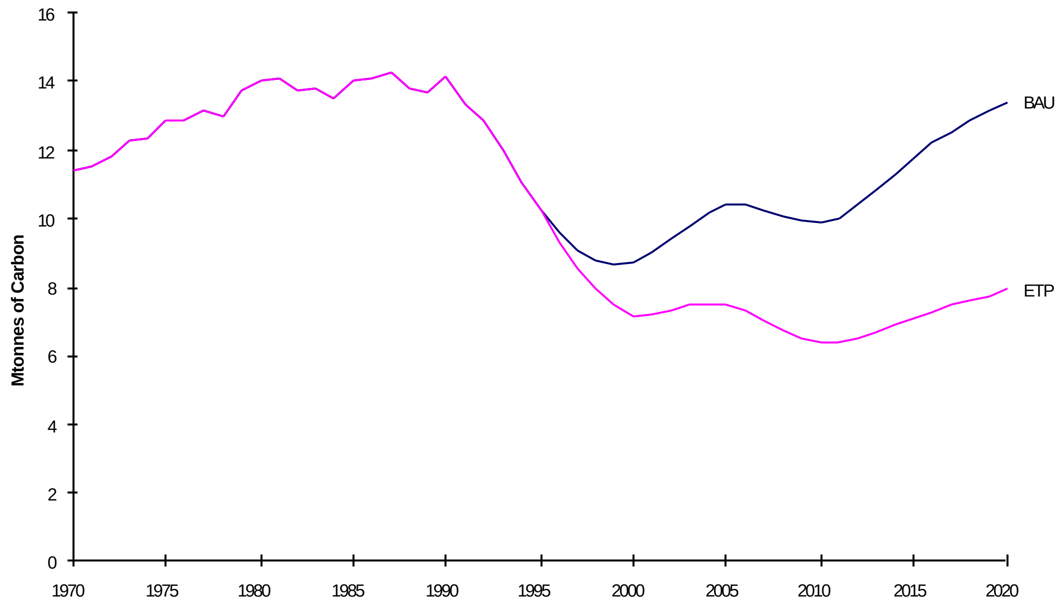


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**Figure 8.7 Carbon dioxide emissions from lights and appliances under the BAU and ETP scenarios, UK 1970-2020**

Savings examined so far have been discussed in terms of electricity consumption per annum. These can be converted to financial benefits to the consumer using a price of 7.5 pence/kWh: by 2020 the saving would be worth £75 each year for each of the 28.5 million households in the UK.

The ETP savings in electricity, consumer expenditure and carbon emissions from generation are summarised in Table 8.2. Over the period 1995-2020, the cumulative value to consumers of electricity savings (at 1994 prices) could be £43.4 billion if all the ETP is accessed in full. Although a hypothetical figure, this demonstrates the substantial financial benefits that could accrue to consumers from energy efficiency improvements. There would also be a saving from carbon dioxide emissions of 5.2 MtC, with a cumulative total saving of 81.1 MtC over the period.

**Table 8.2 ETP savings in terms of electricity, money and carbon dioxide, UK 2020**

| | **BAU** Electricity (TWh) | **ETP** Electricity (TWh) | **BAU-ETP Saving** Electricity (TWh) | Electricity (%) | Money (1994 £bn) | $CO_2$ (MtC) |
|---|---|---|---|---|---|---|
| Cold | 15.6 | 4.1 | 11.5 | 73.5 | 0.86 | 1.9 |
| Wet | 11.0 | 8.2 | 2.7 | 25.0 | 0.21 | 0.5 |
| Brown | 11.7 | 8.0 | 3.7 | 31.5 | 0.28 | 0.6 |
| Cooking | 16.5 | 11.4 | 5.1 | 30.9 | 0.38 | 0.8 |
| Lighting | 19.1 | 10.1 | 9.0 | 47.1 | 0.67 | 1.5 |
| Miscellaneous | 9.1 | 9.1 | - | - | - | - |
| **Total** | 83.0 | 51.0 | 32.0 | 38.6 | 2.40 | 5.2 |
| **Cumulative** | | | 578.3 | | 43.4 | 81.1 |

## 8.5 CONFIDENCE IN MODEL OUTPUT

The DECADE team have confidence that the findings given in this report represent a considerable improvement on past estimates of electricity consumption in lights and appliances. However, some variables have been measured more accurately than others, for instance household numbers, ownership and sales. Technical efficiency over time is now moderately well understood for the major appliances. There is, however, a paucity of usage data on many appliances and available measurements are usually based on small samples, that may not be representative. Further improvements to the model output would come from better data and the search continues. However, there are limited remaining opportunities to obtain historical data and increase the accuracy of the analysis.

The data have been used to determine the important variables that have contributed to historical consumption. Figure 4.3 showed the impact on electricity consumption in washing machines of technological, usage and demographic factors in the form of indices. These factors are used as the basis of the scenarios. The benefit of this approach is that it makes it easier to develop projections as well as making them transparent. Inevitably, the further the data are projected into the future the greater will be the possible error, but new data can be used to correct the assumptions easily with the DECADE approach and this is what occurred with the revisions to population forecasts after the 1991 census. In addition, the projections are based on a cautious approach and with values close to their current levels.

Undoubtedly, further improvements could be made to the model. No allowance has been made for any deterioration in the efficiency of an appliance over its life: it is assumed to be as efficient on the day it dies as the day it was bought. Another uncertainty is whether, with some appliances, a significant number of machines are owned, but not used, for reasons of economy. For instance, low-income households are known to limit use of a tumble dryer when the weekly budget becomes particularly tight. In both these cases, reliable data have not been found.

With each appliance group, the modelling used for the cold appliances is particularly robust. There has been a detailed study performed by the Group for Efficient Appliances, that produced a large amount of technical data. There is also a close resemblance between energy used under test conditions with actual energy usage in the home. In addition, the estimated consumption using test data and the stock model has been validated by measured data. The ETP scenario is also well defined, with considerable savings from appliance replacement and with little takeback potential. Perhaps the greatest uncertainty is the extent to which there will be an increase in frost-free freezers and fridge-freezers and the extent to which this would cause an increase in energy consumption.

Lighting is perhaps the least certain of the appliance groups. The model is sensitive to assumptions about bulb lifetime. If the lifetime of an incandescent bulb in practice is 900 hours rather than 1000, then total consumption by this bulb type will be 10% lower. However, the trend (ie the assumed slope of the projected consumption) is based on sales figures and will not be greatly affected. The ETP scenario for lighting is particularly sensitive to assumptions about purchase price of CFLs, and thus the number of fittings in which they are cost effective. In addition the actual savings from bulbs are dependent on the extent to which improvements in efficiency are taken as increases in service. At present, there has been an increase in burning hours (reflected in growing light bulb sales), and this is projected to continue, together with a slightly higher number of burning hours in the ETP scenario than in BAU scenario to account for some takeback.

Cooking consumption is also difficult to project since many underlying social trends are difficult to translate into energy terms, for example, the impact of an increase in convenience foods and eating out. The whole of the ETP scenario is based on the assumption that electricity and water prices do not change and that the purchase price of the equipment remains at present levels. These assumptions are the only practical choice without a much broader range of scenarios and more detailed economic and technical analysis.

## 8.6 COMPARISON OF RESULTS WITH OTHER STUDIES

Confirmation of the DECADE results comes from comparisons with other studies. The average household in the UK in 1994 used 3000 kWh for lights and appliances. This compares with measured consumption in 100 Danish households by the Technical University of Denmark which found an average annual consumption for lights and appliances of 3200 kWh. Whilst the DECADE findings have increased household electricity consumption for lights and appliances by 7-8% above previous estimates, the Danish data confirms that this is a plausible figure.

Based on observed appliance technology and use patterns, and replacing appliances with the best on the market, it was calculated that electricity consumption in Danish households could be reduced by 47% to 1730 kWh pa (Thomsen 1994). The DECADE findings demonstrated a 39% saving from implementing the ETP scenario in 2020 and March Consulting (1990) estimated 40% savings from replacing the major appliances with the UK best. All three studies are, therefore, reporting savings of a similar magnitude.

Even when the appliances replaced represent the best existing technology, considerable savings can be obtained. NUTEK have conducted measurements in 66 households for one year before replacement of appliances, and for another year after replacing some appliances. Savings were for the cold appliances 70%, dishwashers 34%, washing machine 23%, cookers 6%, while installation of 6 CFLs had no measurable effect on consumption. If these findings were replicated in the whole of the housing stock in Sweden, it is calculated that total savings from major appliances would be 18% (NUTEK 1995:118). In particular, some improvements in efficiency were taken as increases in service, especially lighting. As the appliances were replaced with current market technology not ETP, further savings are possible, for instance in cooking.

## 8.7 CONCLUSIONS

After examining the total consumption in the BAU and ETP scenarios, the main findings may be summarised as follows:

- appliance consumption has almost doubled over the last 25 years,
- consumption is projected increase by another 12 TWh from 1995 to 2020,
- exploitation of the full ETP could reduce consumption by 39% from the level projected in 2020,
- $CO_2$ savings are dominated in early years by changes in the electricity supply industry,
- towards 2020, policy is needed if emissions from appliance consumption are not to return to 1990 levels,

- the quickest savings are through lighting efficiency gains, and
- the largest efficiency gains are in cold appliances and lighting.

It should be emphasised that the ETP scenario includes a reduction in consumption from those technical improvement which are currently cost effective to the consumer given current equipment, electricity and water prices. It does not represent the technical limit for improvement. Nor does it include any reductions in consumption from changed usage patterns (such as reduced wash temperatures). It does not in any way represent therefore, the lower limit on consumption that could be achieved through both consumer education and further technical improvements.

To achieve the economic and technical potential, a variety of policies will have to be introduced, and a combination of policy instruments is likely to be most effective. These have been described in the policy initiatives chapter (Chapter 2) and the individual appliance chapters. There is further discussion of policy implementation in the concluding chapter (Chapter 11). Before this, however, the next two chapters describe the work being undertaken by the DECADE team to examine behavioural factors and to build these into a sub-model. The latter, PRIME, considers the potential savings offered by behavioural responses to a range of policies.

## 8.8 REFERENCES

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## CHAPTER 9: CULTURAL AND BEHAVIOURAL ISSUES VERONICA STRANG

### 9.1 INTRODUCTION

One of the key aims of the DECADE project has been to incorporate into the model the cultural and behavioural issues that affect energy use and thus $CO_2$ emissions. This involves an analysis of the relationship between socio-cultural influences, beliefs, knowledge and values, their expression in particular actions and the ways in which they affect receptivity to energy saving policies.

As these are largely qualitative issues, DECADE has chosen to take a dual approach: a reductionist analysis that attempts to quantify the data for the purposes of the model, and a more detailed qualitative analysis that gives fuller explanation of the complexity of the issues. These analyses will be complementary, with the preliminary statistical analysis helping to develop the qualitative analysis, and this, in turn, leading to more targeted statistical work.

This chapter focuses mainly on DECADE's efforts to quantify behavioural data and integrate them into the model. The more readily quantifiable behavioural data - levels of consumption, usage patterns and ownership of appliances - are dealt with elsewhere in this report; the concern here is with the factors which, although less tangible, represent a considerable underlying influence for all of the groups (government, manufacturers, retailers and consumers) represented in the model. At this stage of the project DECADE has been concerned mainly with the consumers and their decision-making processes, but as some of the preliminary work with retailers indicates, it would clearly be beneficial to consider the values and consequent actions of other groups in the equation as well.

The issue of causality is central to the behavioural aspects of DECADE's work, and the current research is aimed at tracing the connections between situational and demographic factors, influential background factors, knowledge, attitudes and values, and actions and policy receptivity (for fuller discussion, see DECADE 1994). The theoretical assumption is that there are meaningful relationships between each of these as illustrated by the following:

**Situational/demographic factors**
(eg socio-economic class, income, housing, gender)
=>
**Socio-cultural factors**
(eg early learning, personal/family history, institutional culture)
=>
**Knowledge**
(eg awareness of environmental and energy issues, technical literacy)
=>
**Beliefs and values**
(eg view of Nature, level of concern for the environment)
=>
**Actions**
(eg chosen style of energy use, 'green behaviour'[1])
=>

[1] 'Green behaviour' is defined through a set of indicators, such as recycling, efforts to reduce energy consumption, purchasing of 'environmentally friendly' products and suchlike.

**Policy receptivity**
(eg responses to real or proposed policy instruments)

In order to trace this ‘causal chain’, we needed a holistic data set that would allow us to follow the connections through with our informants, and it was decided that the best way to achieve this was with a pilot survey focused on a small sample population.

## 9.2 DECADE PILOT SURVEY

### 9.2.1 METHODS

A first step in preparing the survey was an extensive literature search to consider a range of comparative statistical and qualitative research in Europe, the USA and the UK. An overview of this work will be incorporated in a report following the qualitative analysis of the DECADE survey, due to be carried out in the Spring of 1996.

Given the policy evaluation aims of the DECADE project, the pilot survey focused on people buying a cold appliance following the introduction of energy labeling in January 1995. Although this made creating a demographically typical sample more difficult, it did permit an analysis of a real policy.

The sample was gathered through a leaflet placed in fridges at a range of retail outlets. Without revealing the precise nature of the project, the leaflet invited people to discuss their decision-making in exchange for a small fee. Once they had responded, a brief telephone interview was conducted, with some preliminary questions that made it possible to build a demographic range reflective of the wider population. The respondents needed for the sample population were sent self-completion questionnaires, and were later interviewed at length about their values, sources of information, energy and environment related behaviour and responses to policy. Though the interview was structured, in having a series of core questions, it was designed also to permit in-depth discussion of issues as well. Efforts were made to interview as many members of each household as possible, with a special questionnaire for children.

Where possible, the questions asked duplicated some of those used in wider surveys (eg the DOE Survey of Public Attitudes to the Environment (1993) and the annual British Social Attitudes Surveys) so that comparisons could be made with results from their much larger sample groups. Other questions were designed by the DECADE team to 'fill in the gaps' in the required data set.

With collaboration from colleagues at the Lothian and Edinburgh Environmental Project (LEEP), 200 households were included in the survey. The respondents’ answers to questions were then encoded in an SPSS database for statistical analysis.

### 9.2.2 INTEGRATION OF BEHAVIOUR INTO THE DECADE MODEL

One of the aims of this analysis is to create 'profile groups' or typologies enabling integration of the survey results into the DECADE model, hence providing it with some behaviourally predictive capacity. The process of sub-modeling through which these groups may be extrapolated to represent the wider population within the model is discussed in Chapter 10 of this report.

## 9.3 RESULTS

Since the data collection for the DECADE survey has only recently been completed, the following results are very preliminary. Further analysis will doubtless alter the picture somewhat, but this ‘first look’ gives some promising leads and also suggests that, as was proposed theoretically, it is possible to demonstrate some causal coherence in people’s decision-making.

## 9.4 BACKGROUND FACTORS

The 'background factors' in the DECADE survey consist of basic demographic information and those variables which other research has correlated with environmental concern and 'conserving behaviour'. Their inclusion in our survey therefore has three functions:

- to provide part of the context essential for the creation of strong profile groups;
- to consider the relationship between these factors and behavioural issues;
- to facilitate the use of the sample group as an indicator of the wider population.

The survey points to several variables that appear to be important both for building profile groups and extrapolating these to represent the wider population. One of the most useful findings (especially in terms of providing a 'backbone' for profile groups) were clear correlations between socio-economic class and knowledge about environmental issues, environmental concern, 'green behaviour' and receptivity to various policies.

This finding tallies with the 1993 British Social Attitudes (BSA) survey, which found that activities expressive of concern (eg recycling or membership of environmental organisations) were more often carried out by people in higher socio-economic groups. The BSA survey also found a link between educational qualifications, environmental knowledge and concern. DECADE's findings point to a strong positive correlation between knowledge about issues and level of education.

However, the relationship between socio-economic group and environmental concern or action is at least partially influenced by level of income and a commensurate ability to choose 'green' options - being able to afford membership of environmental groups, (eg BSA 1993). It is invariably difficult to parse motives for 'green behaviour' and to know to what extent cost-saving rather than environmental concern is the aim. In DECADE's survey, older people reported more 'conserving behaviour' and 'green behaviour' but did not express particularly high levels of concern, and were least well informed about environmental issues, which suggests motives more related to early learning with a stress on 'not wasting things', and a practical need to save money.

Gender also appeared to be a relevant variable. The data suggest that women had a greater willingness to make sacrifices and take responsibility for environmental care, and were more likely than men to prioritise Nature over technology. This shares common ground with the BSA survey, which found, more generally, that women expressed higher levels of environmental concern, and with surveys elsewhere, in which as Lutzenhiser says:

> Energy-related gender difference within households have been reported, with women viewing conservation more seriously, and men being less willing to accept regulations in domains of traditional male competence. (Lutzenhiser 1993:263)[2]

These findings are relevant not only in terms of policy design and targeting, but also in view of micro-level studies (eg Wilhite and Wilk 1987) which identify important differences between male and female spheres of energy-related activities.

## 9.5 SOCIO-CULTURAL FACTORS

There is increasing consensus on the need to place energy use and decision-making within their complex social and cultural context. For example, cultural belief systems, role models, the environment of information and imagery, all play a part. These kinds of factors, and the values arising from them, underpin human decision-making, providing an underlying rationale for actions that may, on the surface, appear

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[2] For example, see Claxton *et al*, 1983.

illogical. While most actions are rationalised, generally in economic terms, it is probably fair to say that this is consequent to a decision-making process based largely on subjective (and often unconscious) evaluation (Strang 1994).[3] The factors that construct a particular emotion/mind-set are therefore crucial. As one study comments (citing Lantermann *et al.* 1992):

> Emotional involvement... is a necessary precondition for concrete implementation of pro-environmental values and attitudes. (German Advisory Council 1994:174)

A preliminary analysis of the DECADE survey not only confirms links between demographic and situational factors and environmental concern, knowledge, action, and policy receptivity, but also suggests important correlations, albeit more subtly, between these and less tangible socio-cultural factors such as long-term residence, community attachment, and early socialisation.[4]

For example, the respondents' levels of attachment to their local community proved to be a highly productive variable, correlating strongly with:

- high levels of environmental concern;
- willingness to take responsibility for environmental care;
- 'conserving behaviour';
- 'green behaviour' (recycling etc);
- environmental activism;
- receptivity to a number of policies.

Early socialisation about Nature and the environment[5] also seemed to be important, not only in helping to construct community attachment, but also in encouraging environmental activism.

Some 'situational' types of factors showed up as having influence too: for example, 'long-term residence' seemed to carry some weight, correlating with a positive attitude to domestic energy efficiency. This is coherent with the findings of other surveys: Hackett and Lutzenhiser (1986), for example, found that long-term residence was influential in encouraging 'conserving behaviour'.

The significance of these more complex factors is, naturally, more difficult to establish with certainty, particularly in a small pilot survey. Issues such as early socialisation or attachment to community do not lend themselves readily to quantification, and although efforts were made to find ways to include them in the statistical analysis, they will probably be more fruitfully examined qualitatively.

Nevertheless, even the initial statistical results confirm that these rather elusive influential factors are worth pursuing. There are some interesting ramifications: for example if, as the results suggest, factors such as high levels of attachment to local community correlate with good receptivity to a range of policies, this clearly has implications for policy development and implementation.

When appraising socio-cultural issues, it is also important to take into account the smaller-scale institutional and household 'cultures' that provide the most immediate context for human action. These 'mini-cultures'

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[3] In previous work (Strang, 1994), I have defined the process of evaluation as a dynamic interaction between subjective (emotional) and objective (intellectual) judgements.

[4] This can be defined as the process by which social norms, cultural values and beliefs, knowledge etc. are inculcated in children.

[5] This was based on questions about whether respondents had learned much about these during childhood, and the sources of such information at that stage.

with their particular belief systems and values can be highly influential, with potential outcomes ranging from staunch maintenance of current norms to encouragement for radical alterations in behaviour (Strang 1995). This view is supported, for example, by a study comparing two very similar housing complexes, in which variations in consumption levels suggested that 'locally evolved' standards of behaviour can make a considerable difference (Hackett and Lutzenhiser 1986, 1991). These smaller contexts have relevance not only for the creation of household or community profiles, but also as a way of considering the behaviour of people within particular institutional frameworks (eg manufacturers and retailers).

## 9.6 KNOWLEDGE

### 9.6.1 Understanding of environmental and energy issues

There is widespread agreement that knowledge about environmental issues is essential in motivating changes in energy-use behaviour. Sadler (1982) argued that consumer ignorance about energy conservation prevented 'energy saving' from becoming a winning concept and eliciting R&D and investment from manufacturers.

Levels of energy 'literacy' are a strong influence on willingness and ability to conserve (Ester 1985).[6] More recently, Hedges (1991) noted the importance of knowledge about environmental issues and the effects of consumption in motivating 'conserving behaviour'. He also defined a lack of understanding of the relationship between domestic energy consumption and global warming as one of the major obstacles, a barrier confirmed by Kempton (1993). In the UK, a Department of the Environment survey (1993) found that less than half of the respondents could define the correct cause of global warming, and 38% imagined that it was related to the hole in the ozone layer.

In the DECADE survey, 33% of our respondents thought that the hole in the ozone layer was the cause of global warming, and a further 25% thought that it might be. Only 10% could be said to be well informed about environmental issues in general.[7]

### 9.6.2 Understanding of technical and economic aspects of energy use

The ability to connect domestic energy use and global warming is not the only important factor; more immediate and practical aspects include the understanding of the relationship between energy and cost savings, or the technical proficiency necessary for good energy management.

> Behavioural barriers concern the decision-making of energy users. Lack of reliable information about the financial impacts of different investments of actions, or the difficulty in obtaining it, is especially a problem for households, small and medium-sized companies and small public administrations. Even if relevant information is available, few users perform an economic calculation of costs and benefits, or take a long-range perspective. (Schipper and Myers, 1992:306)

People are frequently confused about the relative efficacy of energy saving measures. For example, Kempton *et al* (1984) found that respondents often thought that behavioural change would be much more effective than making physical or technical efficiency improvements.

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[6] In a 1986 survey, Palmborg also found correlation between attitudes to energy use and levels of household consumption, but he also noted that the households involved displayed no knowledge that domestic energy consumption constitutes a third of total energy use.

[7] ie were in the top quartile.

In a survey of 60 women on a Leeds housing estate, over half of the sample group were found to have little or no knowledge about the running costs involved in their electricity usage, and this was particularly so in the older age groups (Bagshaw 1981). There was a lack of understanding of basic energy principles, and of the technology relating to energy use (eg many respondents did not use the timer on the central heating).

There is also a strong positive correlation between educational levels and understanding of both general and technical issues. In a 1991 DOE survey, 61% of those with degrees and 58% of those with A levels could point to the correct causes of global warming (Hedges 1991). This educational aspect is particularly important, given the relationships between knowledge and concern, changes in behaviour and receptivity to policies.

Our own results find common ground with these surveys. Only 30% of people had a good understanding of the causes of global warming, but this percentage increased with educational levels. When it came to more immediate technical understanding, the relative consumption of various appliances was well understood by 45%, but only 20% had a good understanding of the relative efficacy of a range of energy saving measures.[8] In the sample population, levels of education were also strongly correlated with a range of important variables including:

- awareness of current educational campaigns;
- general environmental knowledge;
- understanding of the relative consumption of various appliances;
- understanding of the technical aspects of energy use;
- a positive attitude to domestic energy efficiency;
- willingness to make sacrifices and take responsibility for environmental care.

## 9.7 ATTITUDES AND VALUES

From an anthropological viewpoint, behaviour is generally agreed to be the outcome of socio-cultural beliefs and values. However, in other disciplines the strength of the link between attitudes and values, and behaviour has been fiercely debated. The current general concensus is that, provided they move beyond more superficial attitudes, researchers can expect to find some coherence between values and behaviour, unless other factors (eg economic realities) intervene.

A greater understanding of the importance of cultural beliefs and values has led to the acknowledgment that, in comparison with more superficial attitudes or opinions, they are not as malleable or inclined to change. Energy use, like most patterns of behaviour, is heavily subject to long-term values and habit (Palmborg 1986). One survey of a large number of households found that there was almost no evidence of changed behaviour during the energy crisis years of the 1970s (Lundstrom 1980). The variation between households remained constant, and the houses themselves showed no energy memory.

While cultural values may only shift slowly, there is evidence of some change. Inglehart has charted what he describes as an increase in 'post-materialism', essentially a rejection of values centred on consumption (Inglehart 1977, 1989). Increasing concern about the environment is recurring in most of the regular large-scale quantitative surveys. For example, in a 1993 MORI poll, 31% of the respondents prioritised the environment over the economy, in comparison with the 15% who felt that priority should be given to the economy at the expense of the environment. 12% felt that the environment should be protected at all costs

[8] ie were in the top quartile.

(Worcester 1994).[9] The 1993 DOE survey found that 85% of their respondents said that they were 'very' or 'quite' concerned about the environment, with only 14% professing to be 'not very' or 'not at all' concerned.

These results are reflected in the DECADE survey, in which 90% of the respondents professed to be either 'very' or 'quite' concerned about the environment. As has been indicated, this concern meshes with variables such as socio-economic group, community attachment, 'green behaviour' and policy receptivity.

The DECADE survey also included questions designed to examine issues such as Inglehart's 'post-material' values and evaluations of Nature *vis a vis* science and 'modern life'. Opinions about the relative value of Nature and technology correlated with knowledge about environmental problems and the willingness to make sacrifices in order to do something about them. 'Post-materialism' in respondents linked with a number of significant variables, such as socio-economic group, environmental knowledge, concern about environmental problems, 'green behaviour' and receptivity to various policies.

The survey asked more pragmatic questions about the priorities that people had in choosing the fridge that they bought. While these were very down-to-earth, it should be remembered that material culture is heavily symbolic, and choices made in this area are likely to be quite good indicators of values (Lutzenhiser 1993). Nevertheless, as the process of decision-making is generally described in explicit, rational terms, the questions were framed accordingly, and in a way that permitted comparison with other surveys.

Low running costs and low energy consumption are parameters that appear to have taken on greater significance to purchasers of appliances in recent times. The 1994 DOE Omnibus survey, for example, found that for people buying a fridge, running costs were 'very important' for 41% of their respondents, and `quite important` for a further 43%.

In the DECADE survey, 15% said that 'how much energy/electricity it would use' or 'how environmentally friendly it is' was the most important factor influencing their choice of fridge. The four most important considerations were:

- purchase price (35%);
- how well it would work (20%);
- energy efficiency or 'environmental friendliness' (15%);
- place of manufacture (15%).

## 9.8 ACTIONS

Links between levels of environmental concern and 'conserving'/'green' behaviour have now been quite firmly established in a number of surveys. As well as noting an increase in concern, the 1993 MORI poll found that the number of people purchasing green products has doubled in the last five years to the level at which 50% of respondents reported buying ozone friendly products, and 71% bought recycled products. There have been similar shifts in the proportion of people taking five or more listed 'green' actions, this being 14% of adults in 1988, and 29% in 1994.

In the 1993 BSA survey, 71% of the respondents said that they made a conscious effort to save electricity but, significantly, the primary reason given for this was financial.

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[9] This is echoed in an EU survey in 1992, which found that 85% of the population viewed environmental protection as being an immediate and pressing problem (11% more than in 1988).

In the DOE 1993 survey, nearly half of the respondents carried out some environmental activities, for example 25% regularly recycled cans and 44% took bottles to the bottle bank. Despite the small sample size, DECADE's results matched this quite closely, with 25% recycling cans and 48% recycling bottles.

In the DECADE survey, 12% of our respondents were in the top quartile in terms of carrying out a range of ‘green behaviours’, and 28% could be categorised as environmental activists.[10] Our survey also confirms the link between environmental concern and ‘green behaviour’, and shows good correlations between concern, action and policy receptivity.

Environmental activism is perhaps the clearest indicator of deeply felt environmental concern, being relatively unclouded by economic motives. In the DECADE survey, as well as being predictably linked with concern and ‘green behaviour’, activism correlated positively with socio-economic group (as suggested by the 1993 BSA survey) and, significantly, with early socialisation, intensity of current socialisation,[11] post-materialism and attachment to community.

## 9.9 POLICY

In the behavioural causal chain, 'response to policy' is the final link. The profiling of respondents includes a ‘policy receptivity’ rating based on their answers to questions about various policy instruments and, where possible, on actual behaviour (eg where people had had the opportunity to respond to the energy label). Being largely hypothetical, however, this is the area in which DECADE’s findings are most tentative. It is possible to draw, to some extent, on the experiences of other countries, but given the wide cultural differences, this has limited comparative value.

Some factors are essential for the success of any kind of policy instrument (eg knowledge, concern, and genuinely practical and affordable options), but there are many other important factors that affect policy success. They include timing, public perceptions about the source of the policy, levels of flexibility and confidence in the economic climate, and media support. Another important and complex question concerns the combination of policy instruments and the potential for cumulative or exponential effects.

At this stage in DECADE's behavioural work, the priority has been to create profiles of population groups that contain some indication of their potential responses to policy, but there is a lot more work to be done on this, and on developing modeling formulae which will permit an assessment of scenarios comprised of more than one policy instrument.

### 9.9.1 Energy labels

It was hoped that, as an actual policy, energy labeling would provide DECADE’s survey work with the most reliable information about consumer responses. However, although the scheme was instituted officially in January 1995, the reality was that even several months later, when the fieldwork was being carried out, a number of retailers did not display labels on their fridges. Consequently, many of our sample 'fridge buyers' did not have the opportunity to respond to them. According to Wattanasuwan’s investigation of retailers’ responses to the scheme, there was some confusion as to whether the responsibility for placing labels on appliances lay with manufacturers or retailers (Wattanasuwan 1995).

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[10] This involved activities such as supporting or donating money to environmental groups, signing petitions, participating in protests or demonstrations, and lobbying M.P.s.

[11] This factor was based on the current number of named sources of environmental information cited by respondents.

The DOE Omnibus survey (December 1994), found that, a month before the energy labeling scheme was due to begin, only 20% of their respondents[12] had heard of the scheme. This was, once again, correlated positively with socio-economic group and thus with educational levels.

In the DECADE survey, only 37% of the respondents reported that the fridge they bought had an energy label.[13] This meant that the sample group became small for a confident statistical analysis of their responses. However, as these questions were explored more fully in the interviews, a qualitative analysis may add to the reliability of what follows. The extent to which respondents said the label had influenced their purchase decision was:

- 'a great deal' 15%;
- 'quite a lot' 19%;
- 'somewhat' 32%;
- 'not at all' 35%.

This was reflected in the actual ratings of the fridges purchased: there was a positive correlation between stated levels of influence and sales of more energy efficient appliances.

Further, of those respondents who did see a label, 58% said that it had explained the appliance's efficiency in ways that they could understand easily, though 63% would have liked more explanation, either on the labels, through the sales staff, or on a poster in the shop. They were fairly evenly divided as to which of these would be the best source of further information.

We also asked our respondents what was the most important kind of information on the energy label, producing the following ratings:

- running costs (46%);
- efficiency rating (33%);
- energy consumption (17%);
- an environmental message (4%).

The recent DOE Omnibus survey found a general preference (68%) for having both the comparative energy use and total electricity consumption per year shown on the label[14] but DECADE's results suggest that information about running costs would be even more welcome.

One outcome of the DECADE survey that may prove useful in predicting responses to energy labels was the apparent link between levels of knowledge and understanding of the technical aspects and cost benefits of energy use, and the amount of influence of the label. This was supported by another variable relating to the focus of the respondents' type of education or type of work. People whose work or educational background is focused on scientific and technical types of activity were more receptive to the label. This has obvious implications for educational policies.

Receptivity to the label also correlated with levels of environmental concern, socio-economic group, post-materialism and, notably, sympathy towards other types of policy, in particular those involving regulation and some extra cost for 'environmental friendliness'.

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[12] Comprised of people who helped to choose or pay for domestic appliances.

[13] This may be because the labels had yet to be placed in the fridges, or that the repondents were unwilling to admit that they didn't remember.

[14] There was an interesting difference here: more women than men felt that labels should contain both - the total breaks down into 56% men and 68% women.

These results are only preliminary, and due to the slow implementation of the labeling scheme, still contain a number of unanswered questions. However, linked with Wattanasuwan's related findings and experiences elsewhere, they do seem to indicate that it is essential to consider the responses of all the groups involved in the process. For labeling to become effective, it needs strong support from retailers and effective public information (eg posters in shops and information in the media).

Another important factor is the general 'environmental literacy' of the population, and their familiarity with the technical and cost-related aspects of energy use, factors that relate to education and early socialisation. This finding is illustrated by the evident range of responses in different countries, with the suggestion that variation in national populations' levels of concern and knowledge is a major factor.

> If 'energy illiteracy' - lack of information regarding the severity and scale of environmental problems, relative energy prices, and consumption alternatives - limits consumers' capacities to compare costs and formulate action plans, then the delivery of high quality information might be expected to result in greater conservation response. (Lutzenhiser 1993:253)

### 9.9.2 Efficiency standards

Although this policy instrument is generally seen as being aimed at manufacturers, an important part of the 'context' for its implementation is the level of public support for legislation. This ties in with the issue of who is perceived as having the responsibility to solve environmental problems. For example, in 1991, 84% of people in the USA thought that energy was a serious problem, and most saw business and industry priorities and government decision-making as 'the major obstacle to the country using energy more efficiently' (Farhar 1993:xvii). There are also questions as to what effect the introduction of legislative policies might have on the public's response to other kinds of policy instrument. A number of attitudinal studies (eg Millstein 1976 and 1977, Ritchie and McDougall 1985) have suggested that the public will respond more positively to a variety of policies if they feel that the burden of change is being shared between industry and all social groups. In addition, some research has considered levels of trust in institutions, and the effect of this on responses to a range of policies. Results from the DECADE survey suggest that low levels of trust in business and government may be influential in discouraging environmental concern and action. It is possible that positive action by the government regarding minimum standards, and a sympathetic response from industry, would have 'knock-on' effects in educating consumers and persuading them to make more energy-conscious choices.

DECADE found that 97% of respondents[15] favoured stricter pollution controls for industry, which tallies with the DOE 1993 findings (96%). 78% of the DECADE respondents thought that government should limit the use of cars in cities (DOE 75%), and 59% thought that there should be stricter controls on vehicle emissions (DOE 87%). More pertinently (and predictably less enthusiastically), 18% thought that the government should restrict or ration household energy use.

It was notable that legislative policies appealed most to people who felt strong community attachment and environmental concern, who rejected material values and scored highly on 'green behaviour'. They were also more receptive to other policies.

### 9.9.3 Rebates and grants

Various socio-cultural issues need to be considered in assessing schemes centred on financial incentives. Non-financial social factors can be very important in determining the likely success of rebate and grant

[15] These figures are a combination of respondents who "tended to support' or "strongly supported" these measures.

schemes. For example, there are conflicts with such as comfort, appearance, and avoiding hassles, and obstacles such as lack of sufficient or accurate information, restricted choice or lack of trust in the sources of information (Stern *et al.* 1986). For some people financial assistance may have negative connotations for their self-image or social status.

Financial factors are also important. High-income groups may not think the amount saved worth the effort. An issue for very low-income groups might be the lack of resources to make an investment or their ability to deal with high rates of payback.

The source of the assistance is also relevant: as one US marketing scheme discovered, rates of response to an incentive scheme varied considerably according to whether it originated from the utility company or the more ‘trustworthy’ county (Stern *et al.* 1986).

In the DECADE survey 85% of the respondents said that a rebate would encourage them to buy a more energy efficient appliance, although 51% thought that there might be problems with such a scheme. In more general terms, 77% felt that the government should provide grants for insulation and, as the 1993 DOE study found, there was wholehearted support for subsidising and improving public transport.

### 9.9.4 Educational campaigns

As pointed out in Chapter 2, it is notoriously difficult to assess the effectiveness of broad educational campaigns. For example, though there has been an increase in environmental concern and ‘green behaviour’ in recent years, it is very hard to separate and evaluate the relative effects of media information, changing values, and various educational efforts. Nevertheless, energy literacy and knowledge about environmental issues are crucial ingredients in forming people's concern, influencing their actions and their responses to policies, and it appears that education campaigns remain an important background for the successful implementation of most policies.

In 1987, Meyel found that 95% of a small sample group were not aware of national campaigns of any kind, and a similar percentage ignored leaflets relating to energy saving because they distrusted the sources. In 1991, a DOE survey found that most people were still unaware that domestic fuels contribute to $CO_2$ emissions. Another 1991 survey found that people's concerns were still mainly focused on issues such as acid rain, which had received a lot of media coverage (Hedges 1991). Numerous other surveys in the interim have cited consumer ignorance of the issues as a major obstacle.

However, in 1993, a MORI poll found that 87% of the respondents wanted more information about environmental risks (Worcester 1994). In the same year, a DOE survey found that 54% of its sample group 'strongly supported' and 37% 'tended to support' inclusion of environmental issues in the school core curriculum. In DECADE's survey, these percentages were 65% and 26% respectively.

Given the recent increases in school work on energy and environmental issues, and the various wider educational campaigns with particular appeal to children, it is of interest that our survey results point to higher awareness of environmental problems in the younger age groups. Unfortunately, because of the necessary selection of a fridge buying sample group, the youngest age cohorts were not well represented. Where possible, our interviewers did try to include all members of the household, but this did not encompass a significant number of children and teenagers. Nevertheless, the hint that younger people were better informed is useful, and could be followed up on relatively easily with a small school survey project.

The DECADE survey did ask some questions about where people got their information about environmental and energy issues. Predictably, the media appeared to be the most commonly mentioned sources of information:

- television 85%;
- newspapers 72%;
- radio 42%.

However, there were other more immediate (and possibly more influential) sources:

- children in the family 28%;
- neighbours 26%;
- leaflets 25%.

50% of the respondents had ‘seen or heard something about energy efficiency recently’, and 38% remembered what this had said.

The DECADE survey also attempted to get some feedback on a range of campaigns, picking up a question from the DOE's recent Earth Panel Survey (the results of this have yet to be announced). The question asked which slogans people remembered seeing or hearing:

- ‘Wasting energy costs the earth’ 38%;
- ‘Reduce, reuse, recycle’ 31%;
- ‘Save energy, save the earth’ 31%;
- ‘Think globally, act locally’ 19%;
- ‘For all our tomorrows’ 18%;
- ‘Helping the earth begins at home’ 15%.

Those who recognised most slogans on the list were, in general terms, younger, above average in their concern about the environment, were more knowledgeable about it and more inclined to conserve energy where possible. They were also willing to take responsibility for environmental care, and to make sacrifices in order to solve environmental problems, claiming to be more receptive to environmental taxes and regulatory policies.

### 9.9.5 Feedback

As the 'Ecofeedback' campaign in the Netherlands demonstrates, there are some potentially useful ties between general campaigns and targeted information giving households feedback on their energy saving. Feedback on energy bills can satisfy a number of the criteria deemed to be important in getting effective results, offering personalised and relevant information, and tackling some of the difficulties that many people experience in relating energy conservation information to expenditure.

Whether linked with wider campaigns or not, feedback programs have produced promising results in various EU countries (see Chapter 2). In the UK, billing processes are not immediately compatible with the requirements of a feedback programme since bills are infrequent and do not make it easy to keep track of costs (Hedges 1991). Meters are rarely visible and do not give cost information. In 1987, Meyel found that more than 40% of her informants could not recall even rough estimates of their last two fuel bills. More than 50% did not know where their gas or electricity meters were, and of those who did, 45% could not read them.

92% of people in the DECADE survey said that they did keep their bills, at least as receipts. When asked to estimate what proportion of their household budget they spent on energy, most overestimated this, with only 38% suggesting that their expenditure constituted between 5 and 10% (the national average is in fact between 4 and 10%).

### 9.9.6 Targeted advice

In 1987, Meyel found that 95% of her informants had never attempted to seek advice on energy efficiency, and did not know where to seek such advice. Since then, various utilities have expanded their advisory services and a number of Local Energy Advice Centres have been established. However, Meyel's finding that most people distrusted the utilities (and presumably any advice they might offer) still appears to hold true, with the DECADE survey suggesting that 80% of the respondents had low levels of trust in government and industry.

It is too soon to assess the effect of Local Energy Advice Centres (LEACs), but they undoubtedly have the advantage of being perceived as impartial and also of being local. This would seem to bode well for their effects, given the apparent links between strong community feelings and environmental knowledge, concern and action.

In the DECADE survey, 11% of the respondents knew that their area had a LEAC, and 75% said that they would welcome someone coming to their home to give advice on household energy saving. 55% were willing to pay for this advice and of these 41% said they were willing to pay up to £10; 41% up to £25; 15% up to £50 and 2% were willing to spend more than £50. The respondents' receptivity to LEAC's activities was, again, linked to socio-economic group and, in particular, high levels of environmental concern.

One of the most untapped areas for targeted energy advice in the UK appears to be the retailers, as demonstrated by the low response to the labeling scheme. As Wattanasuwan (1995) has described, very little has been done to encourage retailers to give their sales staff training about energy efficiency ratings, or to provide them with educational materials (eg posters advertising the labeling scheme and comparing appliances' actual running costs or annual savings). Yet various studies confirm her view that the sales staff are generally seen as the most useful source of information in purchasing household appliances (Wilkie 1994, Olshavsky 1973, Willet and Pennington 1966).

Schemes such as the Danish pilot project cited in Chapter 2 (Jeremiassen 1994) suggest that results can be more readily achieved with significant staff training though, again, there are cultural differences to be considered here. In the DECADE survey, 33% rated the sales staff as their first choice as a source of further information on energy efficiency.

### 9.9.7 Higher costs

Although this is not a policy instrument as such, it is included here as a potential outcome of policies that increase the costs to industry. Various studies suggest that many people are willing to pay extra for products that are 'environmentally friendly'. In a US survey, 64% of people said that they would be willing to pay up to 10% more for groceries to be sure of not harming the environment, and this contention is borne out by the marketing of such products, which almost quadrupled in 1990 (Kempton 1993:221). However, the 1993 MORI poll suggests that in the UK public statements of good intention are not borne out by the marketing figures, and Worcester (1994) suggests that such assertions are little more than 'lip service'.

In the DECADE survey, 64% of the respondents said they would be 'very' or 'fairly'willing to pay higher prices in order to protect the environment. 11% were 'very willing' to accept cuts in their standard of living in order to do so (we gave as an example of this 'restricted car use') and 33% were 'fairly willing'.

If Worcester is right, then investing in energy efficiency clearly has better prospects for people than simply paying more for products and receiving no benefit. Sadler found that almost all of his respondents thought that energy efficient appliances were

> ...an excellent idea and well worth paying a little extra for, provided that the additional cost was saved on running costs in the first year. (Sadler 1982:11)

This question is obviously heavily subject to economic realities, and it is clear from the correlation of variables on this issue that the people expressing willingness to pay more are mainly the ‘greenest’ respondents (high income and education, strong community feelings, well informed about environmental issues and domestic energy use, very concerned about the environment, very active with ‘green’ and ‘conserving’ behaviours and supportive of legislative policies). They are also, therefore, well equipped to assess the benefits of investing in energy efficiency.

Energy pricing is a somewhat separate issue, presenting consumers with much less freedom of choice. Quite apart from ethical concerns for lower income groups, there is some question as to whether even quite large energy price increases have more than a short-term effect on levels of consumption. Much depends on the elasticity of demand, however. With luxury items such as air conditioning, there is an indication that energy prices have a strong impact in the long run (Kempton 1993).

However, looking at more general household consumption patterns in the UK, Hedges found that one of the main things to emerge from his survey was an inelasticity of demand (Hedges 1991). Apparently most people felt that there was a narrow band of acceptable comfort level which would be minimally affected by price rises.

### 9.9.8 Energy taxes

This policy instrument consistently receives the lowest levels of support. However, energy taxation has two vital differences over higher costs coming to the consumer via industry: it gives the opportunity for the extra money to be channeled directly back into solving environmental problems or to other benefits to the public, and it can feasibly permit means-testing to ensure that lower income groups do not suffer. In the light of current controversies about privatisation, directors’ salaries and trends suggesting increasing environmental concern and demands for social equity, it may be that the climate of response for energy taxes, particularly if these are imposed on industry as well as domestic consumers, is undergoing some change.

Recent responses in favour of this policy instrument remain low though: in 1993, the MORI poll found that only 28% of the respondents favoured an energy tax on household electricity or other fuels. In the 1993 DOE survey, only 3% of the respondents ‘strongly supported’ energy taxes though a further 16% ‘tended to support’ this policy. In the DECADE survey, the comparative figures were 6% and 19%. The DOE found 62% opposed to energy taxes, and DECADE found 63%.

DECADE respondents in favour of energy taxation were similar in type to those who supported increased prices. One notable difference was that, as a group, they were above average in being able to recall several educational campaign slogans.

## 9.10 CONCLUSIONS

To date, DECADE has only conducted a small pilot project, and the results described above are of a preliminary nature, but it is reassuring that where other surveys have covered aspects of the data and asked similar questions, the responses are not dissimilar.

The next major stage of DECADE’s behavioural work will involve a proper analysis of the survey responses, ironing out anomalies, examining the apparent linkages more closely, and testing these within the theoretical framework. This will lead into the qualitative analysis and more sophisticated statistical investigation.

One of the major challenges is to find ways to create workable profile groups out of such a complex range of data. This is clearly an area in which it is most difficult to reconcile the practical statistical requirements of the model with the ‘realism’ provided by rich contextual data. Much of the work to date has been focused on developing research methodologies that will bring behavioural data into the model without reducing them to the point where they are separated from their context and therefore inexplicable. This work has to be carried out alongside the process of designing PRIME, the behavioural submodel described in Chapter 10.

Another major challenge is to analyse and find ways to elucidate the relationship between the micro-level data arising from survey work and the broad socio-cultural trends outlined in the various appliance chapters of this report. This needs to be tackled more fully as part of the project’s theoretical core and also, in practical terms, within the model. The integration of micro and macro level analysis is essential if the DECADE model is to be genuinely predictive of behaviour.

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# CHAPTER 10: A POLICY RESPONSE-INTERACTION MODEL FOR ENERGY

DAVID FAVIS-MORTLOCK

## 10.1 INTRODUCTION

A major component of DECADE's *raison d'etre* is to model the effects of policy upon domestic energy consumption. In the version of the DECADE energy model used to produce the results described in this report (Appendix 1), the impacts of future policies are considered implicitly in the ETP scenario. Only those policy instruments (Chapter 2) may be considered which:

- have been put into practice at some time in the past, and for which there are some data regarding response in terms of change in energy usage;
- had this past application in a situation (country, societal group, etc) which is comparable to the situation being modelled;
- might be expected to produce a future response which is broadly similar to past response.

Other future responses which cannot be easily considered are:

- those produced by combinations of different policies;
- responses due to repeated application of the same or similar policy instruments.

A more explicit approach to estimating the effects of future policies on energy usage is therefore the subject of ongoing research by DECADE. This takes the form of a model (PRIME: Policy Response-Interaction Model for Energy) which complements the main DECADE energy model and will be integrated with it in the second phase of DECADE.

## 10.2 THE MODEL

### 10.2.1 Concepts

All energy policies aim to modify the behaviour of one or more societal groups such as manufacturers, retailers or consumers (Chapter 9). An obvious and major problem when attempting to quantify the effects of energy policies is the sheer complexity of interaction within and between such groups. Reactions to policy decisions may vary greatly from individual to individual, and from household to household; only in the large aggregate can a more coherent response emerge. An early decision was taken, therefore, that PRIME would need to work at this level of aggregation. PRIME therefore deals with societal 'actors', each of which is presumed to possess a relatively coherent response to the energy policies under consideration. Such an actor might be (for example) that subset of all UK electricity consumers who would react similarly (in terms of purchasing patterns) to the introduction of energy labelling on cold goods.

Even with this simplification of the problem, interaction between societal actors is not straightforward. The effects of policy changes are dynamic, may well be lagged, and in many cases may only gradually take effect or die away; following such effects, electricity usage may or may not eventually return to its original level. For example, increased electricity costs might be expected to evoke a variety of 'primary' responses from electricity consumers in terms of both usage and purchasing patterns. These would probably give rise to subsequent 'secondary' responses — perhaps in terms of consumption of available appliances — on the part of both retailers and manufacturers. Since the various effects of such responses (in terms of change in energy consumption) will not come into operation immediately, some or all of the responses resulting from this particular policy instrument are likely to be impossible to separate from responses due to other factors. Again, a reductionist approach is essential. PRIME therefore considers only those interactions between actors which are judged to be most important.

The response of each societal actor to particular policy instruments is likely to differ both between appliance groups (increased electricity costs, for example, might be expected to produce different results in terms of usage patterns for lighting and heating) and between different 'attributes' (those considered by the DECADE energy model are intensity of usage, number in use, and efficiency) of the same appliance group. PRIME therefore operates separately for each appliance group/attribute combination.

Lack of data regarding responses to energy policies is a major problem with regard to calibration and/or validation of any quantitative policy response model. Where no suitable data are available, the use of some form of proxy data is the only alternative. In PRIME, this takes the form of expert judgement. However, the use of proxy data in this way will inevitably introduce additional error and uncertainty.

By these means, PRIME seeks to implement what might be described as a more 'process-based' approach to energy policy modelling. In models which represent aspects of the physical environment, the two endpoints of the continuum of possible approaches are (Wilmot and Gaile, 1992):

- empirical, 'black-box' or 'fit' models. These are the simplest. Only the relationships between inputs and outputs are described; examples are regression equations. The main weaknesses of this type of model are that it gives no information about what is actually happening within the system modelled; the model will probably need to be recalibrated before it can be used with other data; extrapolation beyond the range of data used to define the model may well be dubious; long-term trends which are not captured by the model will tend to invalidate it; and since the responses of such models are at best curvilinear, thresholds, instabilities or boundaries in the real system will not be captured (Kirkby *et al*., 1992);
- 'process-based' or 'white-box' models. This type is necessarily more complex, since it also seeks to capture the interactions within the system of interest and use these to describe the relationships between system inputs and outputs. This greater complexity, and the inevitably greater resultant data requirement, are this type's main limitation. Advantages are in many ways the converse of the above-listed weaknesses of empirical models.

In reality, no model is fully process-based; all include some empirical component. PRIME is no exception. Since interactions <u>within</u> each societal group are not explicitly modelled, the model is of the black box type in this respect. However, because of its explicit descriptions of the interactions <u>between</u> societal groups, it represents an important first step toward the process-based ideal.

### 10.2.2 Construction

The modelling strategy adopted for PRIME is to represent, for each appliance group/attribute combination, the temporal flow of policy-induced change through society in terms of flow through a network. PRIME therefore has three conceptual parts:

- a network
- a set of parameters for each node making up the network
- the policy scenario input component

This section also describes links to the DECADE energy model, and PRIME's implementation.

**The network**

The PRIME network represents the main societal actors and their interactions; it consists of 'nodes' (which represent the actors) and 'links' (which represent their interactions). Figure 10.1 gives an example network: those links which are two-way (ie 'top-down' and 'bottom-up') are marked by solid lines; one-way top-down links are dashed; one-way bottom-up links are dotted. (Note that as currently implemented, PRIME considers only top-down links. Bottom-up links are to be be added.)

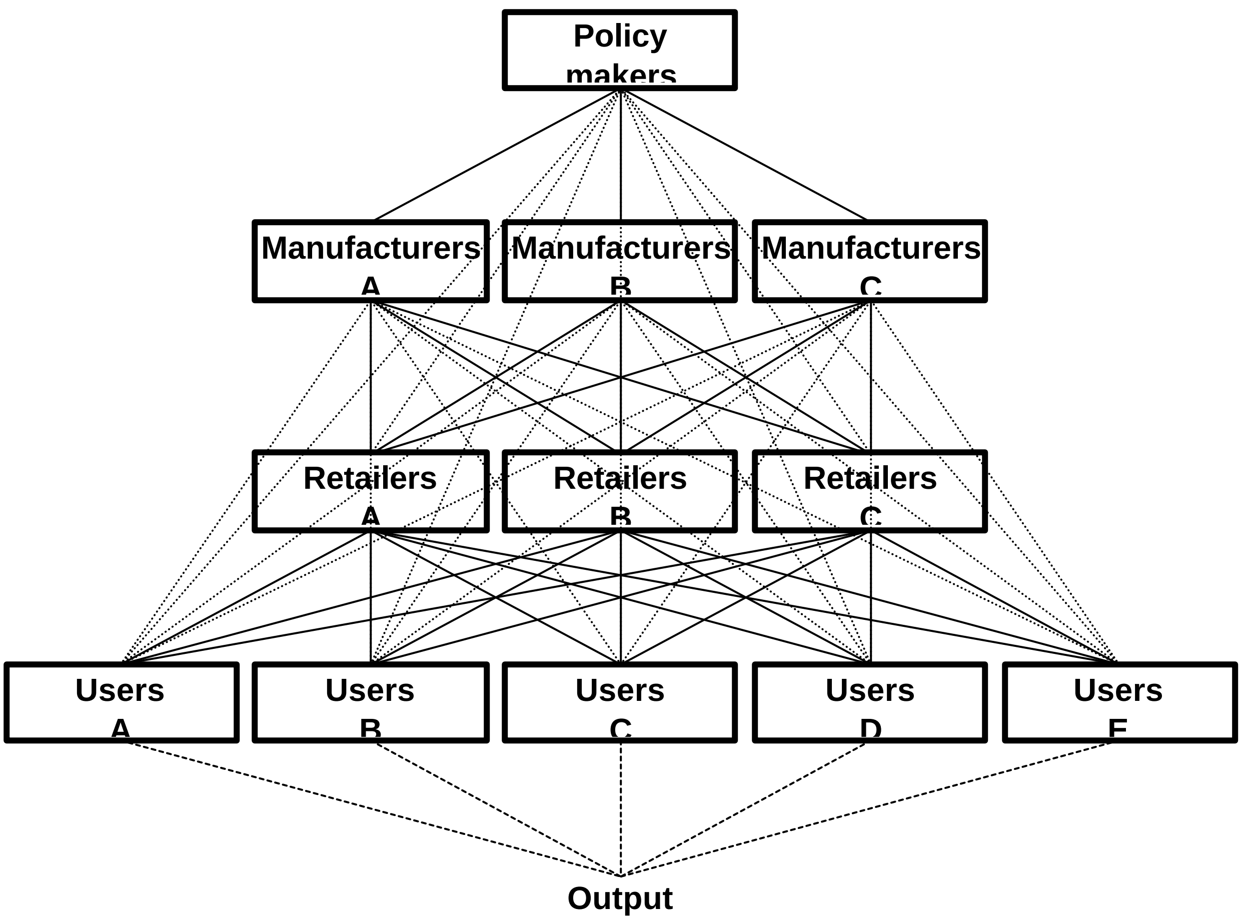


**Figure 10.1 An example of a PRIME network. See text for explanation**

Policy input can enter the network at any node (or nodes). Its effects are then assumed to 'flow' from node to node through the network, using a fixed temporal resolution. This flow eventually reaches the network output, where it emerges as a time series of (for example) changed efficiency for wet goods.

The network in Figure 10.1, with one policy node, three nodes for manufacturers, three nodes for retailers and five for users, represents a prototype design used for initial runs. The three manufacturer and three retailer nodes in this design broadly represent groups having fast, medium and slow responses to policy imperatives. The five user groups have a more objective basis, being drawn from the results of the DECADE consumer questionnaire (Chapter 3). (Note that as currently implemented, all societal groups at the same 'level' — eg all manufacturer groups — are considered to be of equal size.)

**Propagation of change through the network**

In order that PRIME may be used with any of the three attributes used by the DECADE energy model, the 'currency' of the network is defined to be non-dimensional percentage change. This can be positive or negative. Thus PRIME outputs take the form of a time series of percent change in the appliance group/attribute considered (eg change in the number in use for brown goods). PRIME can run with any timestep (ie temporal resolution), though this must be the same throughout a run. All initial runs use a monthly timestep.

Output is thus conceptually straightforward; however what exactly is meant by the units of 'change' represented at PRIME's inputs and during propagation through the network is less obvious. These can perhaps be best thought of as potential change. For example, a typical PRIME run might consider wet goods' efficiency; policy input at a manufacturer node would therefore represent the temporal 'shape' of potential change in efficiency which might be expected of the policy. This shape might for example be a step (see Figure 10.3 below) in the case of a policy based upon minimum standards; or a pulse (also Figure 10.3) for an information campaign. This 'temporal trace' of policy input would then be transformed by the manufacturer node, and passed as a modified time series of potential efficiency change to one or more retailers nodes, modified again by each of these, and passed on to one or more user nodes, where it would be modified yet again, summed, and output as a total change in efficiency. Note that multiple policies may be input.

The transformations carried out by each node are implemented by the use of transfer functions (Box and Jenkins, 1976). These are a form of ARIMA model (Chatfield, 1994). In the current version of PRIME, first-order transfer functions are used. Response *y* at timestep *t* is given by:

$$y_t = ay_{t-1} + by_{t-d}$$

where *a, b* and *d* are parameters. While δ describes the function's lag (units same as the model's timestep), a and b correspond less obviously to any measurable quantity. These three parameters together, however, define the shape of the temporal trace produced from a given input trace, and must be supplied for each link in the network.

**Parameterisation**

Even with a relatively simple network design (eg Figure 10.1), a large number of societal interactions (ie links) are possible. These must all be quantified by supplying values for *a, b* and ♎.

When data from surveys are available, this will be used to define and calibrate the model. In this case, values of the three parameters will be chosen which would reproduce the shape and magnitude of the actor's response to policy change. In most cases, though, such data will not be available. In this case, expert opinion will be used to select values of the three parameters; these will be chosen so that they give a shape and magnitude to the response which appears reasonable. Clearly, for the whole model, two extreme outcomes are possible:

- worst case: complete model defined only by expert opinion, therefore subjective;

- best case: complete model defined and validated from measured data, therefore objective.

At first, limited data sources imply the worst-case scenario. As more data become available, the model will tend toward (but, given the likely timespan of the DECADE project, probably will never reach) the best-case. Preliminary work appears to indicate that the user nodes are most sensitive in determining the shape and magnitude of PRIME's output. First efforts are therefore being concentrated on the parameterisation of these nodes (Chapter 9).

**Links to the DECADE energy model**

Since PRIME produces time series of percent change for each appliance group/attribute, linkage to the DECADE energy model is straightforward (Figure 10.2). These time series (suitably aggregated to a common timestep eg yearly) are used to modify the attribute values held for each appliance group prior to a run of the DECADE energy model.

**Implementation**
PRIME is implemented in Visual BASIC™, and runs under on the PC platform under Windows™. Because of the need for flexibility in the first exploratory phase of research, PRIME is designed to be highly configurable. The three components of the model — network, node parameters, and policy scenario — are largely independent of each other. Thus the same policy scenario may be used with different network designs, sets of assumptions about societal response, etc. A PRIME network is specified by a text file which is input to the model; numbers of nodes and links are limited by available memory, and (more practically) by the user's ability to parameterise these. For a given network design, the node processing sequence is calculated by a depth-first search algorithm employed in (for example)

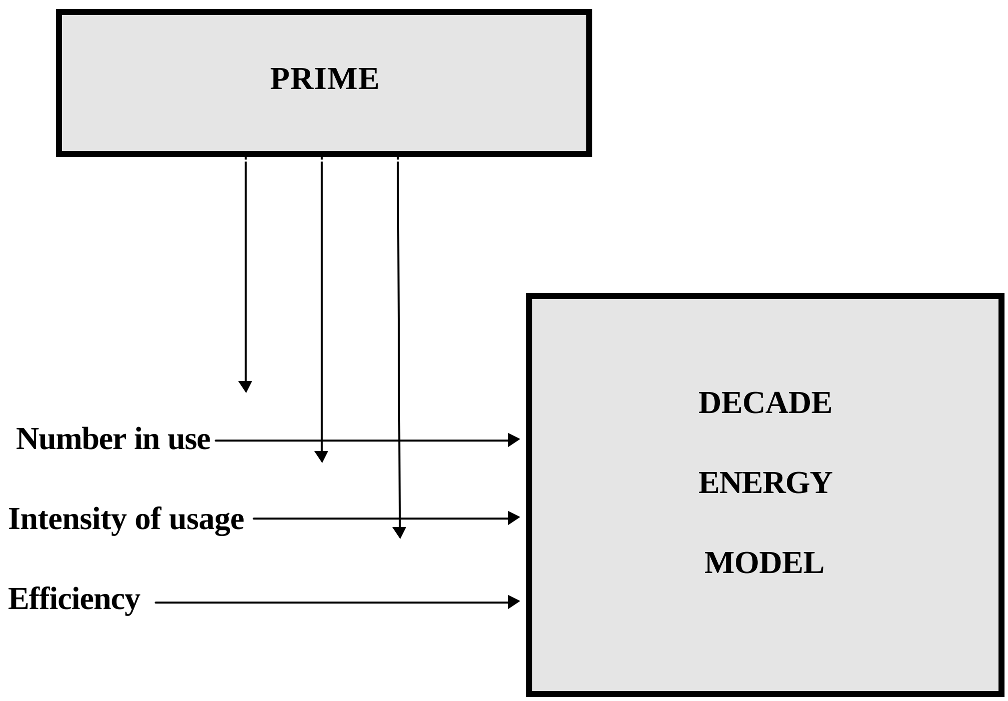


**Figure 10.2 Links to the DECADE energy model**

chess-playing programs (Narayan and Sharkey, 1985). The current version of PRIME allows only top-down flow (cf. Figure 10.1).

Due to the nonintuitive nature of the parameters required for the transfer functions, PRIME allows these to be specified for each link by displaying graphically the response to 'standard' input traces (step, pulse, ramp etc), then modifying parameter values and redisplaying until the displayed trace conforms to the user's expectations.

### 10.2.3 Data requirements
These are summarised in Table 10.1.

**Table 10.1 PRIME's data requirements**

| Data item | What this represents | Source |
|---|---|---|
| network design | for each appliance group/attribute, the 'model's-eye' view of interactions between policy makers, manufacturers, retailers and users | survey and/or expert opinion |
| timestep | minimum temporal resolution of model | expert opinion |
| shape and magnitude of each link's response to 'standard' inputs (set by 3 parameters) | for that appliance group/attribute, the response to policy-induced change of the societal group-to-group interconnection represented by that link | survey and/or expert opinion |
| policy scenario | the temporal trace of potential change likely to be produced at the policy's input node | expert opinion |

### 10.2.4 Assumptions

There are many assumptions inherent in the approach adopted. The first group have already been mentioned in passing:

- A reductionist approach is feasible, ie the dynamics of the policy maker-manufacturer-retailer-consumer system may be adequately modelled by considering only a subset of all conceivable interactions. This is not trivial; some workers in the developing study area of Complex Systems (eg Beck, 1994; Waldrop, 1994) have postulated that the traditional scientific reductionist approach is inappropriate when dealing with phenomena which exhibit emergent behaviour. This may be true of the societal responses to energy policy considered by PRIME;
- Society can be split into groups with a relatively homogenous response to energy policy. First results from the DECADE survey (Chapter 9) appear to confirm this;
- The interactions between such groups can be portrayed as a network. The effects of energy policies may be conceptualised as pulses passing through such a network, with a finite and fixed temporal resolution;
- The responses of the groups represented by nodes in the network to particular policy instruments in the future will be related in some predictable fashion to their response to similar policy instruments in the past;
- Where hard data on the responses of such groups to energy policy are unavailable, expert opinion may be used as a useful surrogate.

Other assumptions are:

- That the response of any societal group to a policy with a 'simple' temporal trace (eg a pulse or a step) is related in some predictable fashion to the same group's response to a more complicated temporal trace. This is difficult to test, but may be true;
- Response to a given temporal trace of policy input will be the same irrespective of the 'type' of policy (eg educational, regulatory, etc). This is unlikely to be true. This problem will be addressed in a future version of PRIME (see Table 10.2 below);
- Response to a given policy trace will be similar irrespective of the 'past history' of the group (in other words, the policy always produces the same response no matter what earlier policies have been

implemented). Again, this is unlikely to be true, and so will be considered in future work (Table 10.2);

- The response of any societal group to policies A and B operating simultaneously is related in some predictable fashion to the same group's responses to policies A and B individually. This is unlikely to be true in every case, since (for example) simultaneous educational policies to reduce lighting use cannot hope to reduce usage beyond some practical minimum. Again, this will be considered in future work (Table 10.2).

## 10.3 PRELIMINARY RESULTS

Some example output from PRIME, based on the network in Figure 10.1, is shown below. It must be emphasised, though, that the model is still under development: values used for node parameters in these runs are arbitrary, and chosen for test purposes only. Similarly, the policy scenarios chosen are intended to be illustrative rather than realistic.

Both examples illustrate the modelled response to a hypothetical two-policy combination, which enter the network at the manufacturer A and manufacturer B nodes, separated by an interval of six months. (Note that in reality, policy input would probably affect — and therefore be input at the nodes for — all manufacturer groups.) The model is assumed in both cases to be considering change in efficiency for some appliance group.

### 10.3.1 Example 1

In this case, the first policy is more permanent: it has a step-like temporal trace, such as might be produced by the introduction of minimum standards regulations. The second is more ephemeral: it has a smaller, pulse-like trace, which might be produced by an educational or information campaign (Figure 10.3).

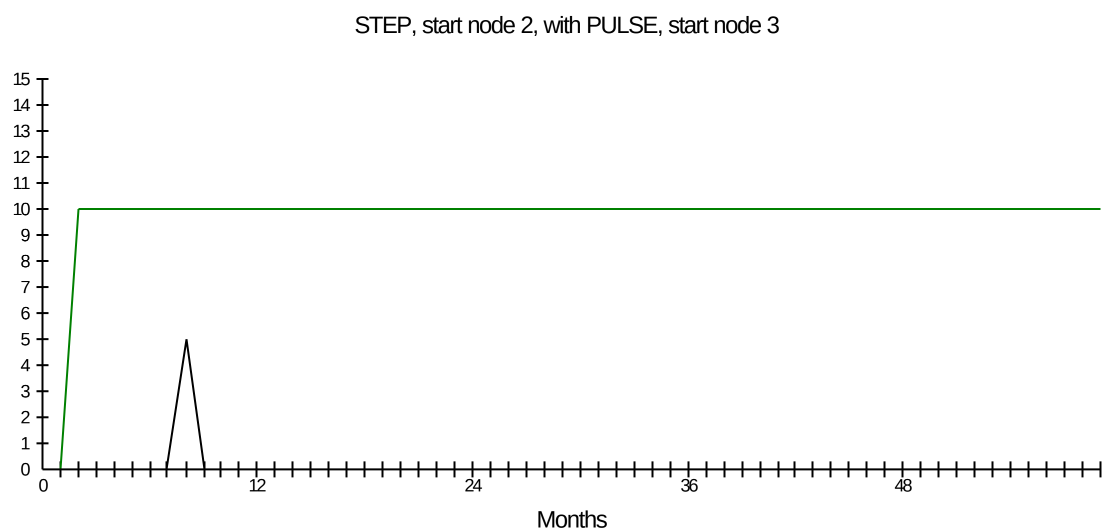


**Figure 10.3 Policy inputs (first example). Y-axis is percent change in efficiency**

The temporal traces of the policies as modified and passed to the three retailer nodes (A, B and C) are shown in Figure 10.4.

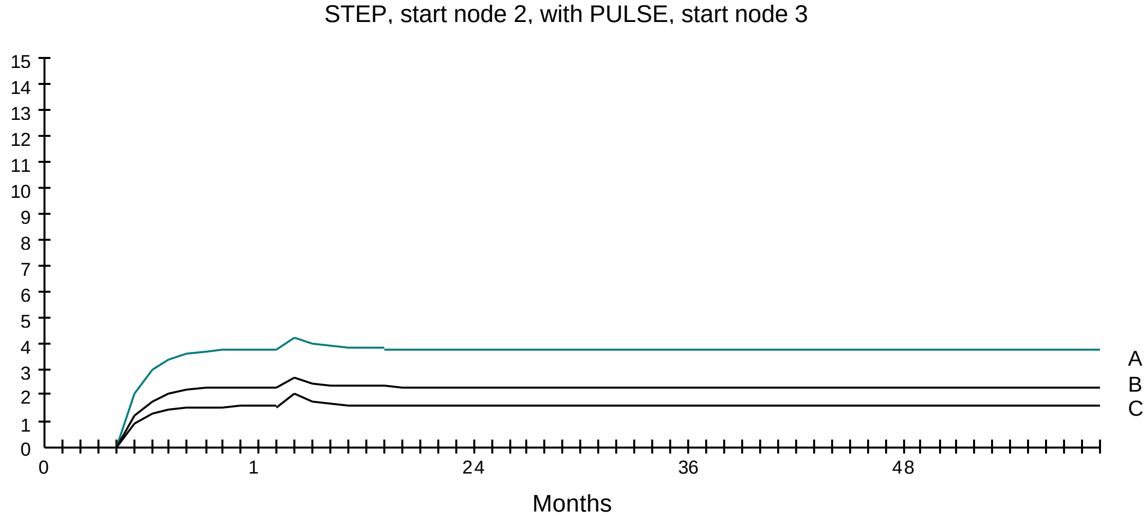


**Figure 10.4 Policy responses passed to retailers (first example) . Y-axis is percent change in efficiency**

Figure 10.5 shows policy-induced change as passed to the five groups of users (A to E).

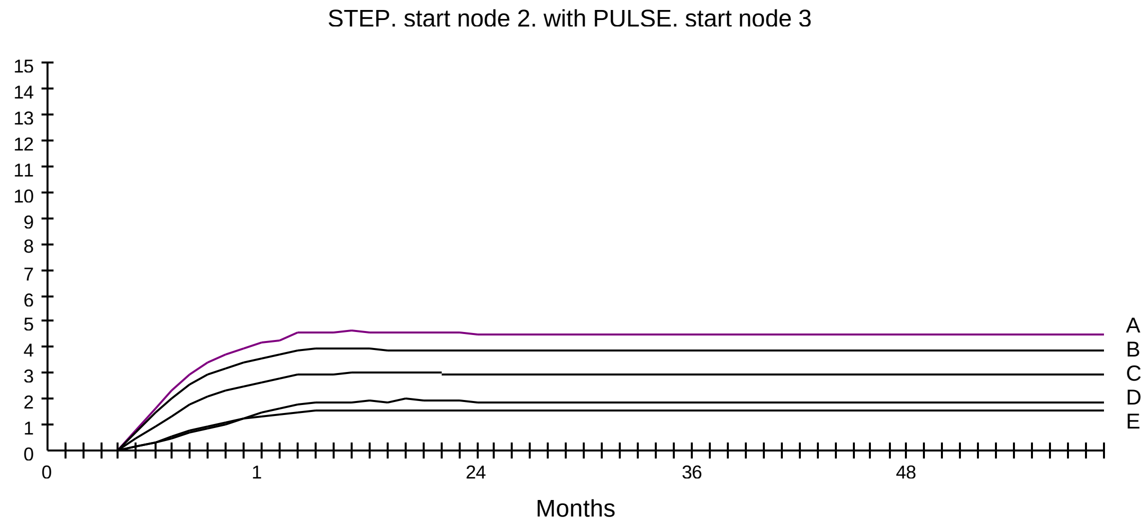


**Figure 10.5 Policy responses passed to users (first example). Y-axis is percent change in efficiency**

Finally, the model's estimate of temporal change in appliance group efficiency is illustrated in Figure 10.6.

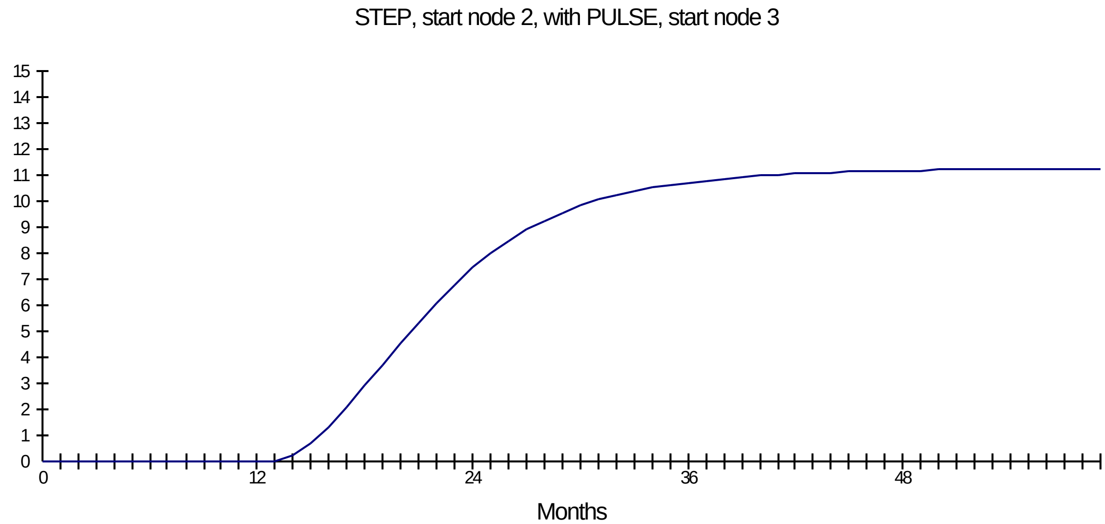


**Figure 10.6 Estimated change in appliance efficiency (first example). Y-axis is percent change in efficiency**

### 10.3.2 Example 2

For the second example, both policies have a step-like temporal trace. However the effects of the first (and larger) policy are positive (ie designed to increase appliance efficiency), while the effects of the second policy are negative. This combination might be produced for refrigerators, for example, by the simultaneous introduction of a minimum standards policy and CFC phase-out. Figure 10.7 shows the policy inputs, Figure 10.8 the responses passed to the retailers, Figure 10.9 the responses passed to the consumers, and Figure 10.10 the estimated change in appliance group efficiency.

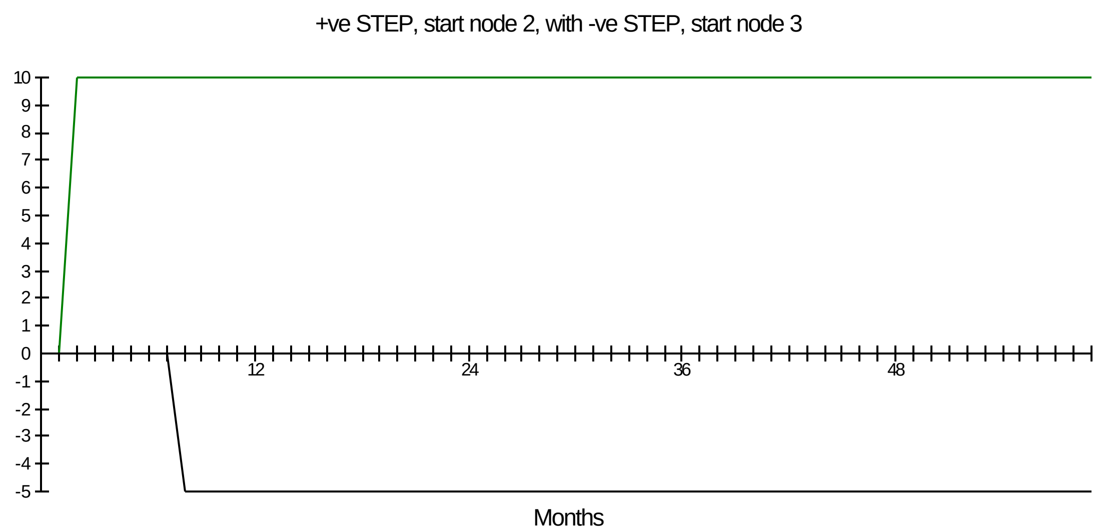


**Figure 10.7 Policy inputs (second example). Y-axis is percent change in efficiency**

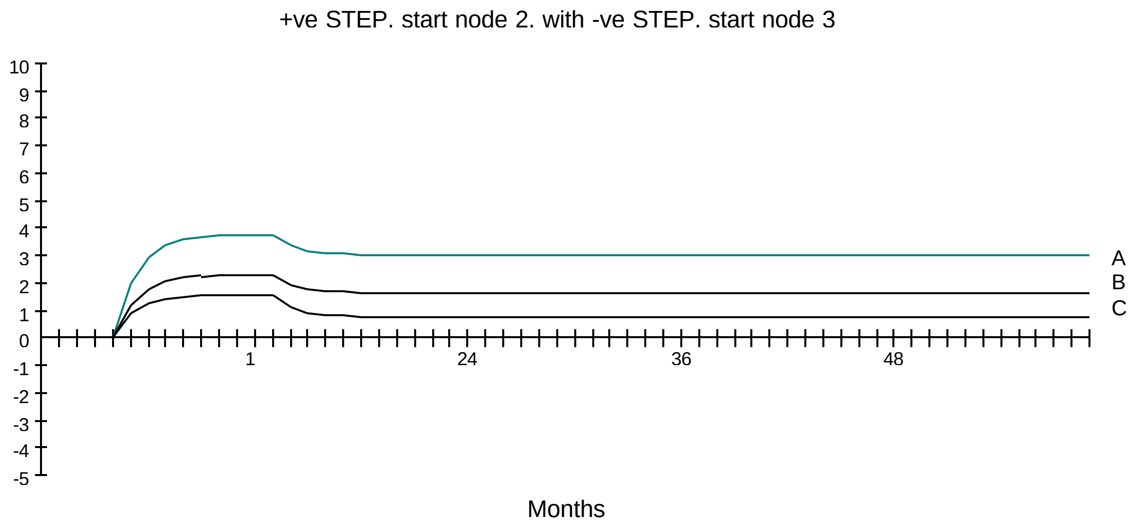


**Figure 10.8 Policy responses passed to retailers (second example). Y-axis is percent change in efficiency**

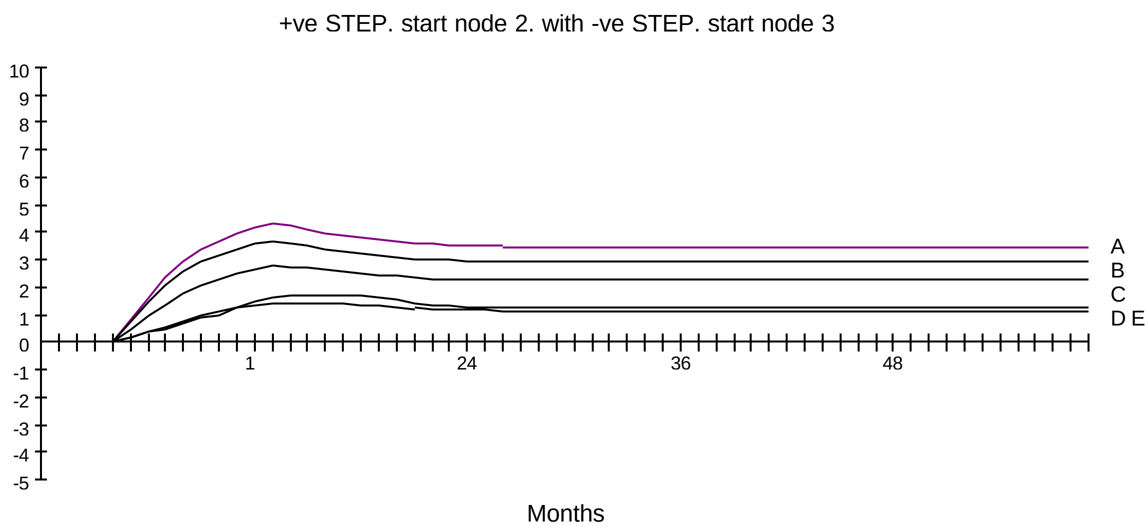


**Figure 10.9 Policy responses passed to users (second example). Y-axis is percent change in efficiency**

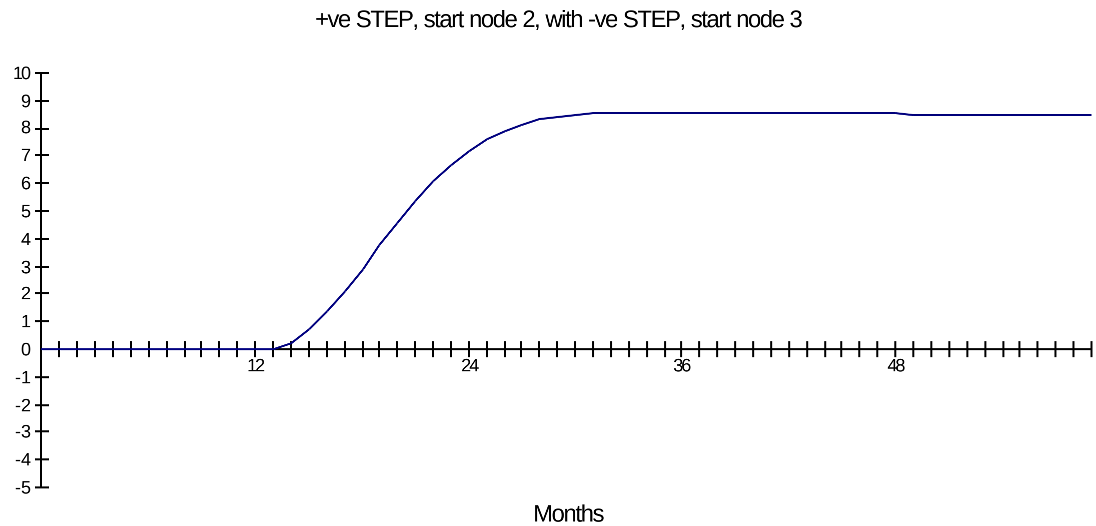


**Figure 10.10 Estimated change in appliance efficiency (second example). Y-axis is percent change in efficiency**

## 10.4 FURTHER WORK

As it stands, PRIME now appears capable of producing responses to simple policy inputs which at first glance appear reasonable. However, it is still incomplete and is yet to be tested on a real-world problem. Plans for further development are summarised in Table 10.2.

**Table 10.2 Future developments to PRIME**

| Present limitations | Model implications if problem to be overcome | Envisaged solution | Implications of solution |
|---|---|---|---|
| policy response always returns to original level eventually | | use second-order transfer functions | data requirement increased, since one extra parameter will be required for each link |
| policy operates only from the top down | ‘bottom-up’ feedback loops needed (cf. Figure 10.1) | add | will greatly increase data requirement if all possible links are modelled |
| same-level groups assumed to be of equal size | | add | data requirement increased, since one extra parameter will be required for each node |
| combination of policies gives no opportunity for positive or negative synergies | currently, when inputs are merged, only simple addition is used | add option for non-linear combination of node inputs | further increase in data requirement |
| response to a given policy trace does not change with time | node parameters need to be varied during a run | add | further increase in data requirement |

**Table 10.2 (continued) Future developments to PRIME**

| Present limitations | Model implications if problem to be overcome | Envisaged solution | Implications of solution |
|---|---|---|---|
| response to a given policy trace is always the same irrespective of the 'type' of policy | node parameters may need to vary with the policy type | add as option | further increase in data requirement; this would be particularly difficult to parameterise |
| no interaction between change in attributes for a given appliance group | model will need to be run concurrently for all three attributes of each appliance group | add? | further increase in data requirement; also increase in computer memory needed |
| no interaction between appliance groups | model will need to be run concurrently for all appliance groups | add?? | further increase in data requirement; also considerable increase in computer memory needed |

The overall effect of incorporating all these developments would be to greatly increase the model's data requirement, possibly to the point of unworkability. Therefore a balance must be struck between comprehensiveness and practicality. More complicated models are not always better, given the greater opportunities for explosive growth of error within such systems (Berryman and Munster-Swendsen, 1994; Leenhardt *et al*., 1994).

Looking to the more distant future, current work on evolving systems (so-called 'artificial life': eg Roetzheim, 1994; Waldrop, 1994) has been remarkably successful in capturing the behaviour of groups as it emerges from the interacting behaviour of large numbers of constituent components, in response to relatively few and simple rules. Successful application of this type of approach to energy policy modelling would indeed merit the term 'process-based modelling of behaviour'.

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**CHAPTER 11: POLICY SCENARIOS AND CONCLUSIONS** **BRENDA BOARDMAN**

DECADE deals with the electricity consumed in lights and appliances in British homes. Data have been collected and analysed for the period 1970 to 1994 and projected forwards to 2020. The DECADE project combines information about the ownership and use of domestic electrical equipment and covers changes in technology, behaviour and demographic factors, to give a detailed breakdown of electricity consumption and the resultant emissions of carbon dioxide.

Statistical modelling has been used to analyse the data and the careful selection and application of the appropriate techniques is one of the main reasons for improved confidence in the findings. The characteristics of each major appliance group are combined with detailed analyses of appropriate policy options to provide a powerful policy impact assessment tool. DECADE thus has a useful analytical and predictive capability.

## 11.1 HISTORICAL TRENDS

A quarter of all electricity in the UK is now used in domestic lighting and appliances. This level of consumption is 7-8% higher than previously estimated over the whole period 1970-94. Electricity consumption in domestic lights and appliances has grown steadily since 1970 at an annual rate of 3% pa and by 1994 represented nearly three-quarters of all uses of electricity in the home.

The historical growth in electricity consumption for domestic lights and appliances has resulted from increasing numbers of households, more appliances, higher levels of usage, and these have only been partially offset by technology that improves the energy efficiency of the equipment. The major users - lighting, cold, wet and brown appliances and cooking - consumed 93% of the electricity in 1994.

Compared to previous studies, most of the differences have come from lighting: annual household consumption has been increased in all years, and from 1970 to 1994 this resulted in a near doubling of annual household consumption from 375 to 729 kWh. The revision, which is still tentative, comes from both a better model of lighting and data from measured surveys. Even this substantial increase in UK domestic lighting is lower than that found in Denmark, where 100 households averaged 900 kWh pa.

The net effect of all these trends is that each household is using 50% more electricity for domestic lights and appliances in 1994 than in 1970, despite the fact that each household contains fewer people: in 1970 an average of 2.9 people used 2000 kWh pa, whereas by 1994, 2.5 people used 3000 kWh pa.

Some of the increase in energy use results from households obtaining a higher level of energy services. For instance there are more light bulbs per house, a larger volume of refrigerated or frozen space and more hours of television are watched. In other cases, there has been a significant increase in energy consumption to provide minor improvements in the standard of service and benefits to consumers. The main example is the use of standby facilities (to facilitate remote control of TVs and videos). Sometimes behavioural changes have resulted in less energy consumption: since 1970, the average wash temperature is 10 ºC lower resulting in a 10% saving in the energy than would have been used in washing machines.

New appliances are generally more efficient than earlier models, for similar standards of service the largest improvements in energy efficiency have come from cold appliances and in televisions. The appliances sold in shops vary considerably in their energy efficiency and this cannot (without energy labels) be detected by the consumer. For identical levels of service, the electricity consumption of the most inefficient appliance is more than twice that of the most efficient one for cookers, fridge-freezers, washing machines, tumble dryers and dishwashers.

## 11.2 BUSINESS-AS-USUAL SCENARIO

The DECADE business-as-usual (BAU) figures show consumption continuing to rise, but more slowly, at less than 1% pa. The main cause is the continuing rise in household numbers between 1994 and 2020 from 23.5 to 28.5 million. These projections indicate greater growth in consumption than that modelled by the Department of Trade and Industry.

Ownership levels of home computers, dishwashers and tumble dryers are expected to continue to rise. Multiple ownership of TVs and videos - and a further increase in viewing hours - coupled with increased levels of lighting in the home are other reasons. In addition, new equipment includes satellite and cable TV equipment, and home office equipment, such as fax machines and answerphones. Usage levels of most appliances are projected to remain at present levels. Not all technology developments result in greater energy efficiency. Some expected (and already visible) trends will result in higher consumption in future. These include: more standby functions (clocks and standby on microwaves), frost-free freezers and fridge-freezers (which may use 200-300 kWh more compared to conventional freezers), wide screen TVs (14% more electricity per appliance).

With existing policy initiatives, the greatest improvements in the efficiency of the appliances bought are expected to come from the cold appliances (where the underlying rate of change is expected to be reinforced by the existing mandatory energy labels and expected minimum standards); televisions and VCRs (because of manufacturer initiatives) and lighting (consumers will switch to CFLs).

By 2020 household electricity consumption is projected to decline to 2900 kWh pa per household, largely as a result of the improved efficiencies of cold appliances.

## 11.3 ECONOMIC AND TECHNICAL POTENTIAL SCENARIO

The economic and technical potential (ETP) scenario is based on proven technology that would provide economic benefits to consumers. Further design options would become economically justified if current equipment prices were to fall, or if energy and water prices were to rise. The ETP scenario does not include changes in usage or consumer behaviour. These have not been modelled because of the uncertainty of possible savings, so the ETP scenario does not represent the lower limit on consumption.

If government policies could access the full ETP by 2020, there would be a further 39% saving in electricity, below the BAU, and this would be worth £75 per household in reduced annual running costs. Two-thirds of this is in the cold appliances and lighting, although at least 25% of the electricity consumed by each major appliance group could be saved with economic benefits to consumers.

### 11.3.1 Policy choices to access savings

There are important opportunities to reduce electricity consumption in domestic lights and appliances to the benefit of the consumers, the environment and industry. The most effective way to access these savings is through a package of policies involving a mixture of information, incentives and regulation. The potential savings vary both in quantity and in ease of access, for each appliance group and the detailed design of initiatives would depend upon the objectives to be achieved. A resume of the policy framework appropriate to the main appliance groups is given below.

Each policy instrument has a range of opportunities and impacts attached to it. Information programmes (including labels) are quick to instigate, uncertain in effect and are most influential for the period of policy implementation. This is the only policy tool available to influence the way existing appliances are used by their present owners. The extent to which labels will be effective at altering purchase patterns is partly dependent on retailer education, but also on the design of the label, publicity, enforcement and so forth. However, the ability to compare the energy efficiency of similar products depends upon ratings, whether as labels or other information, so that grading is an essential prerequisite for other policies.
Incentive schemes reduce the cost of purchasing more efficient appliances. The cost means that incentive programmes have a limited temporal and spatial effect. The incentive can be attached to the best already on the market, can encourage the owners of the least efficient equipment to purchase new machines, or it can be used to accelerate the development of new technology. In the latter case, technology procurement enables the costs, benefits and drawbacks of emerging technology to be explored before efficiency standards are set. Procurement can also be used to encourage the wiser use of an appliance, through the design of controls, choice of settings and minimising the amount of standby consumption.

Minimum standards can be voluntary or mandatory. Once implemented they have a guaranteed minimum effect on all subsequent appliances sales. The policy effect is permanent - the market is moved. The choice between voluntary agreements or mandatory standards depends upon discussions with the manufacturers, the relationship between EU and UK policies, and decisions about the calibre of imports from outside the EU. There are other equity issues involved: with mandatory standards, non-conforming equipment cannot be sold, even at a discount. This protects low-income households from buying cheap, inefficient appliances that will cost them more over the lifetime of the machine.

In addition to the criteria inherent in policy choice, the characteristics of the appliance category are also important in determining the appropriate types of information campaign, incentive and standards to achieve the maximum savings. The following paragraphs groups the issues of most importance in deciding policy for each of the major appliance groups.

With the **cold** appliances, an effective information campaign would focus on support for the energy labels, through retailer education and the provision of running cost details in shops. Changing consumer use, once the appliance has been bought, will produce minimal savings. Incentives would play an important role in increasing market share of the most efficient technologies, and may access 10% of the total ETP. These appliances are being produced in Europe already, just not bought by British retailers or customers. Encouraging the replacement of some of the oldest machines in the stock would be particularly cost-effective: some are broken and use electricity continuously without the user being aware of the cost. A 40% efficiency standard introduced in 2000 in line with the GEA scenario would provide more substantial savings than any policy in the portfolio. Technology procurement would enable vacuum panel technologies to be investigated, with a good understanding of costs and possible drawbacks. The efficiency of any cold appliance can be compromised by the way it is installed in the kitchen, either next to a cooker or in a poorly ventilated, fitted unit. This raises broader education issues.

For the **wet** appliances, the complexity of the energy label for washing machines is expected to divert consumer attention away from energy efficiency issues. The savings from the introduction of this energy label coupled with lower technical potential are, therefore, likely to provide less opportunities than with the cold appliances. However, the additional information on wash performance will increase the need for informed retail staff. Rebates could be influential if targeted on machines that both wash well and are energy efficient. New technologies could further reduce consumption by 25% and are cost effective, when detergent and water savings are included in the calculations. The cost of water is a particularly strong determinant of appropriate new technologies. An agreement to set voluntary standards of performance is under discussion with European manufacturers. Consumer education on the wiser use of appliances offers considerable potential, for instance on the benefits of washing machine spin speed for tumble dryer users; the effectiveness of cooler washes; and, perhaps, whether as much washing is appropriate. Careful loading of all three wet appliances is an area of further savings and so is the use of hot-fill machines. In the latter case, the improved design of the plumbing system in the house can increase the savings to be made.

With regard to **brown** goods most of the focus is on TVs and videos, as the major energy users in this category. The fast changing technology makes energy labels, and the linked test procedure, difficult to introduce, particularly for the on-mode. User awareness of electricity consumption during standby could produce useful savings and result in more informed purchases. A voluntary agreement on standby consumption (say at 3W, a level similar to the Swiss agreements) may access half of the ETP, and may need supporting by an award label (where the aim was to get 100% of the market to gain the label and meet the agreement). Technology procurement could reduce standby consumption to around 1W on some models. However, mandatory standards would be needed to access all of the ETP. The savings from each appliance vary: standby is the bulk of consumption with VCRs, whereas the on-mode is considerably more important with TVs. There are considerable energy implications from the spread of cable and satellite systems, with additional consumption from transformers and decoders that are always on standby. With all standby, the small savings per user mean that rebates are inappropriate and national approaches the most effective.

For **cooking** appliances, technology procurement which brought together all of the design options to reduce oven consumption into one model would demonstrate whether the design potential is economic and give a good indication of costs and drawbacks. Several technologies exist that could reduce consumption considerably, if they could be made cost effective. Uncertainties about the realistic potential of these developments makes the ETP for cooking the most difficult to calculate. A careful assessment of the technology is necessary before rebates can be recommended. Information on more efficient use (lids on saucepans, limit the time warming up the oven, more extensive use of the microwave) could influence behaviour and achieve, perhaps, a 5% reduction in electricity consumption. These savings would be hard to access and measure. Thermal performance of some **small** cooking appliances (particularly those with substantial heat loss such as coffee makers and kettles) could be improved by efficiency standards controlling an allowable rate of heat loss (similar to building standards). Education on the savings from careful kettle-filling has already been part of a national advertising campaign, but there is still considerable wastage from overfilling and reheating the kettle. Other education programmes could focus on coffee machines and the benefits of using a thermos, rather than the hot plate, to keep drinks warm.

With regard to **lighting**, the key barrier to the uptake of CFLs is ‘first cost’, so rebates have an important role to play, supported by clear information on the benefits of low running costs. These programmes need to recognise the problems of repetitive subsidies. Efficiency standards may access some of the total by increasing the use of electronic rather than magnetic ballasts. Over the longer term, other design factors will be important. These include the use of separate bulbs and ballasts; fittings designed specifically for CFLs; and other methods of embedding the technology change into the fabric of the building and into the culture of lighting design. Education of all those involved in lighting advice - retailers, architects, interior designers - will be influential in determining the speed of adoption, the calibre of design and choice of light fittings.

Miscellaneous appliances, for instance vacuum cleaners and home office equipment could benefit from further study than has been possible here. There is undoubtedly a role for manufacturers to make the most efficient equipment available to the domestic consumer more quickly than is occurring.

## 11.4 RESEARCH CONTRIBUTION

Econometric models assume a causal link between price and consumption. The DECADE project examines elements in consumption which are not linked to price, such as changes in usage and technology and underlying social trends, some of which could be stimulated by government. Such changes can be ignored by econometric models as ‘institutional factors’. The DECADE model demonstrates that data-rich end use models have an important role to play in policy advice quite different from the contribution of econometric models. The detailed design of effective policy depends upon a good understanding of the characteristics of the appliance and its market. Without this attention to detail, the expectations of the policy are unlikely to be achieved.

The complexities of modelling interacting policies that have differential effects over time and on sectors of the population has led to the development of PRIME - a policy response-interaction model for energy. This will provide the basis for judging the impacts of policy initiatives on manufacturers, retailers and consumers. The model will separately assess the effect of one or more policies on the number and type of appliances being purchased, the extent to which each machine is used and the efficiency of the models manufactured. This innovative approach will still depend upon expert judgements and specified parameters.

The DECADE study has advanced understanding of the new concept of Market Transformation. A clear finding is the interactive role of policy, not just between individual policies, but also in relation to the appropriate choice for an appliance group. The careful selection of a set of policies will enable the maximum effect to be obtained in relation to the characteristics of the market, the technology of the equipment and consumers’ awareness of energy efficiency in this setting.

## 11.5 FUTURE WORK

The DECADE team have secured funding for a further 18 months, until June 1997, from the European Commission and the Department of the Environment. During this period, the model will be developed further along a variety of dimensions, including:

- sub-dividing consumption in relation to household characteristics. Analysis to date has been of average household consumption and there are known to be substantial variations according to the number and age of people in the household, income group or geographical region. The analysis will be dependent upon the availability of data that is sufficiently detailed;
- a review of the situation faced by low-income households and the condition of their appliances. Preliminary work with the Lothian and Edinburgh Environmental Partnership involved the Consumers’ Association testing appliances from low-income homes and finding high levels of dangerous or broken equipment;
- the analysis of consumer behaviour and attitudes will be completed, so that there is a firmer base for predicting reactions to policy on the basis of social characteristics. The findings of the first study of recent purchasers of a cold appliance, will establish the direction for the next survey;
- collation of more detailed results from policies giving consumers information and advice, to establish which methods are the most effective at altering the market;
- the PRIME model will be developed and tested using data from known surveys, particularly our own. PRIME will then be integrated into the DECADE model so that the effect of policies can be identified for manufacturers, retailers and consumers.

More detailed assessments of the impact of a portfolio of policies for any particular appliance can be undertaken on the basis of specific objectives. For instance the options could aim to maximise the advantages of appliance labelling and other policies, whilst considering:

- the time scale for and size of carbon dioxide reduction required;
- the level of certainty needed for these reductions;
- the way in which the costs of the incentives are to be apportioned between the various participants;
- the total level of expenditure by government or institutions deemed acceptable;
- and whether any household type will be disadvantaged.

Other developments that will be considered are the relationship between weather conditions and energy demand. For instance, the BBC's finding that 90% of the annual variation in viewing hours can be explained by the weather (Section 5.4.3). Another aspect is the implications of changes in consumption for load management, both in terms of timing of peaks and troughs, and spatial distribution of demand on the distribution system using GIS (Geographical Information Systems). In both these cases, the research depends entirely on the quality of data that can be obtained.

The DECADE revisions to electricity consumption in domestic lights and appliances has implications for past assessments of the amount of electricity being used in domestic space and water heating. The DECADE team are participating in a European Union study on electrically-heated domestic hot water and further research will be required to confirm the subdivision of domestic electricity between these three main uses.

### 11.5.1 Using DECADE to analyse other environmental impacts

The model has been designed primarily to deal with energy efficiency as a major environmental issue that is susceptible to policy actions. The model could incorporate a broader range of environmental issues on a similar basis. The basic stock model methodology, together with the market data base of domestic appliances and information about consumer behaviour, and an understanding of policy options would be equally useful in helping to assess overall environmental impact resulting from the purchase and use of these appliances, and policy options for improvement. For instance:

- life cycle analysis of all appliances, analysis of total solid waste implications of appliances including solid waste production from power stations;
- the growth in water consumption in the home from washing machines, dishwashers, showers, baths and toilets etc, and opportunities for demand management;
- global warming implications of CFC, and CFC replacements in cold appliances, together with an analysis of alternatives such as vacuum panel insulation and projections of future emissions from the stock;
- analysis of the flow of end of life appliances to landfill, and the effect of policies to encourage higher rates of product recovery, design for disassembly and recycling. Such policies include producer responsibility and mandatory product takeback.

## 11.6 CONCLUSIONS

A detailed, flexible model of electricity consumption in domestic lights and appliances has been constructed and has already been used to support policy discussions by the Department of the Environment, the European Commission and the UK's Energy Saving Trust. The findings demonstrate that domestic lights and appliances have been a major source of increasing demand for electricity and will continue to be. The effect of existing policies will be to reduce that demand, but not to prevent further growth, under the business-as-usual scenario.

There are opportunities for substantial improvements in the efficiency of the equipment purchased by consumers and further energy savings from the wiser use of these appliances in the home. These savings will only be achieved by new policy initiatives: they will not be delivered by the market as presently structured.

The potential savings can be gauged from the most efficient machines already on sale in shops and new technologies that are already at prototype stage. If these advanced pieces of equipment could be those purchased by consumers, the financial savings over the period 1995-2020 would amount to £43 bn, at today's prices. All of this benefit would be cost-effective for the consumer and would be paid back through any increases in purchases prices, well within the lifetime of the machine.

As a result of these electricity savings there would be less pollution from carbon dioxide - equivalent to over 5 MtC each year. This would contribute both to Britain's present international commitments to reduce the threat of climate change and any further targets that might be adopted. The savings in money, electricity and carbon dioxide would all be achieved without any diminution of energy services. In fact, the quality of services would improve: well insulated refrigerators keep food cool at a more consistent temperature, ensuring that it remains healthy; an energy efficient oven heats up and cooks the food more quickly reducing meal preparation time; audio-visual equipment that uses less energy, remains cooler and the components have a longer lifetime. The householder has a higher standard of living with more energy efficient equipment, but what are the chances of this revolution occurring?
The policy context is changing in the UK. The regional electricity companies have been required to invest in reducing demand until 1998. This commitment will include £25 m to be spent on transforming the market for more efficient appliances and additional expenditure on the promotion of energy efficient lights.

Energy labels on cold appliances are already mandatory, at the point of sale, throughout Europe and by April 1996 will also be required on the wet appliances. Other initiatives are being formulated by the European Commission, including the more extensive use of energy labels and agreements on minimum standards of efficiency with manufacturers. Both of these could be influential. In practice, the effect will depend upon whether the targets are challenging for the appliance designers, rather than merely reflecting the underlying rate of change. With labels, the impact is strongly influenced by the support given by the national government and the extent to which both consumers and retailers are aware of the existence of the labels and informed about the message they carry.

One reason for the cautious policy approach in the UK is the expectation that the British commitment to reducing carbon dioxide emissions in 2000 will be achieved easily. This projection is based on assumptions about the level of gas-fired electricity generation capacity that will be built and the resultant drop in carbon emissions from electricity use. The DECADE findings question the optimism of the Department of Trade and Industry. As this report has shown in considerable detail, future demand is expected to rise, not to flatten out, even with a cautious approach to future appliance ownership and use. By 2005, DECADE projections are 10% higher than those of the DTI.

With few exceptions, the energy efficiency of an appliance has not been a major selling point in the UK. Even so, for several appliance groups, there is a considerable range in the efficiency of the appliances on the market. A focus on the benefits of greater efficiency, through advertising and information, would inform consumers of the opportunities that already exist and would work towards a transformation of the market for these efficient appliances. As consumers are supportive of both energy efficiency and protection of the environment, retail chains would also benefit from a clear focus on 'green' machines. This in turn would provide a stimulus for manufacturers to develop more efficient equipment and increase production of those models that are already market leaders.

There are 144 million households in the European Union, making it a larger market than the United States of America. European policies define the standard of appliances for all countries exporting to the EU and, therefore, have implications far beyond the fifteen member states. The Czech Republic, Poland, Argentina, Russia and Thailand are all countries known to be watching European decisions on minimum standards. Once the industry manufactures to a higher standard, in order to have access to the European market, it will also be able to improve the standard of appliances offered in other markets, to the benefit of all.

The intention of this study has been to ensure that consumers are able to reduce consumption of energy without affecting the level of performance obtained. On this basis, it has been established that there are substantial savings to be made with all the major appliances and lighting, either by improving the efficiency of the machine purchased or by affecting the way the household uses the appliance, or both.

# *APPENDIX A: METHODOLOGY* *KEVIN LANE*

## A.1 INTRODUCTION

This appendix will give outline methods of:

- the DECADE stock model used;
- the low pass filter employed; and
- the estimates of $CO_2$ emissions from electricity.

## A.2 THE DECADE STOCK MODEL

A bottom-up modelling approach is used. Electricity consumption is based on the number of households and average consumption by each appliance in an average household.

The DECADE model is a vintage stock model, the same as that used for the Group for Efficient Appliances (GEA) wet appliances study (Hinnells *et al* 1995). This type of model allows for the time related effect of appliances moving through the stock of appliances in houses. It also enables the evaluation of the effect of policy options (especially technological ones) on consumption.

A vintage stock model can be used to estimate the amount of electricity consumed by an appliance type each year. For example, the electricity consumption of colour TVs in the year $k$ (for years $k$ = 1970...2020) is given by:

$$Electricity(k) = \sum_{j=1970}^{k} Sales(j) \times Remain(j,k) \times Technical(j) \times Usage(k) \qquad (1)$$

where

*Electricity(k)* is the estimated consumption (kWh) of all the TVs in year $k$
*Sales(j)* are the sales of the TVs in year $j$
*Remain(j,k)* are the number of TVs sold in year $j$ and still remaining in the stock in year $k$
*Technical(j)* is the average power consumption (kW) per TV sold in year $j$
*Usage(k)* is the usage (hours) of the TVs in year $k$

For example, the electricity consumed in 1990 ($k$=1990) will be based on all the machines sold up to this year and still remaining in the stock ($j$=1970...1990), the average new technical performance in these years ($j$) and the number of hours in use in 1990.

Sales may be historical data or estimated from ownership data and appliance lifespans. Projections of sales (1995-2010) are derived from projected ownership levels and average appliance lifespans. Ownership data are smoothed using a low-pass filter (Section A.4).

The function *Remain(j,k)* assumes the lifespan of an appliance takes a normal distribution, with two parameters: the mean and the variance.

## A.3 REDUCED FORM

Where data on average new technical performance or usage data (eg number of washes pa) are not available then a reduced form may be used.

$$Electricity(k) = Household\ Numbers(k) \times Ownership(k) \times UEC(k) \quad (2)$$

Indeed, this is the form used in the first DECADE run (Lane 1995). The unit energy consumption (UEC) is the average amount of electricity consumed in one year by the average appliance. It is thus a combination of technological performance and behavioural usage.

$$Electricity(k) = Household\ Numbers(k) \times Ownership(k) \times SEC(k) \times Usage(k) \quad (3)$$

where *SEC(k)* is the average technical performance of the stock in year *k*. There are few measures of historical UEC data, a notable exception are the Electricity Association's measurements.

## A.4 THE IRWSMOOTH LOW PASS FILTER

This low pass filter smoothes out high variation from year to year, when this is due to noisy data, and, more importantly, interpolates missing data point from time series data. The IRWSMOOTH algorithm is a two pass filter which essentially acts as a two sided exponential smoothing window. Examples of these techniques are given in Young *et al* (1991) and Lane (1992).

## A.5 CARBON DIOXIDE EMISSIONS

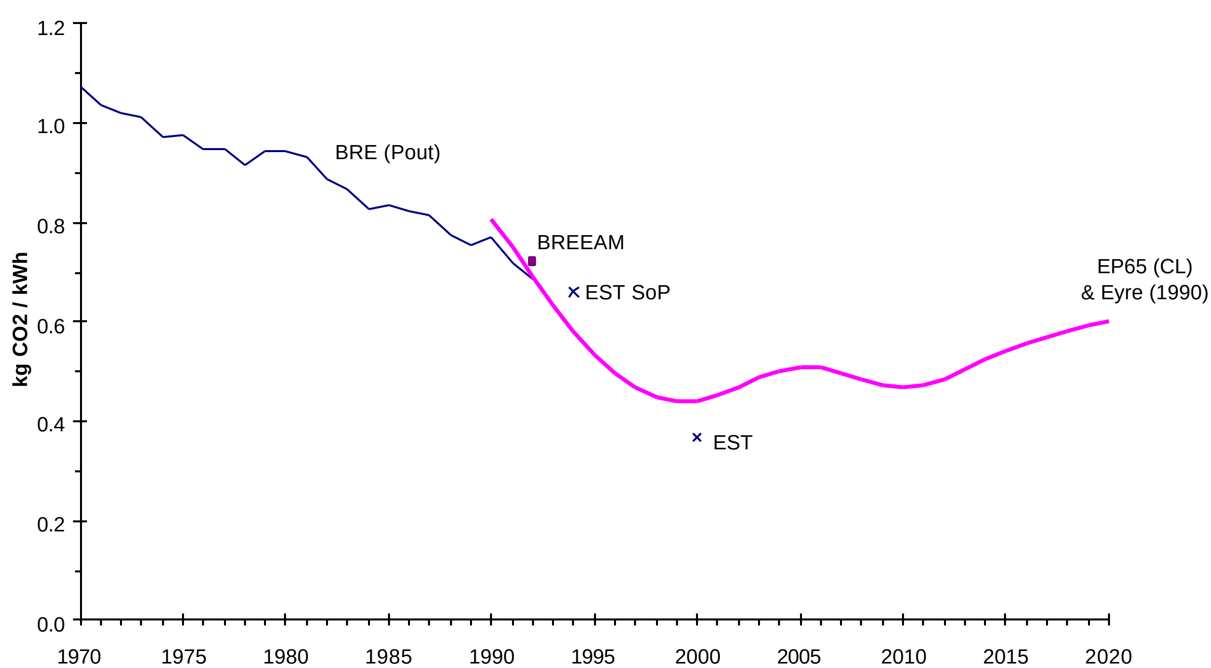


**Figure A.1 Carbon dioxide conversion figures used in the DECADE model, UK 1970-2020**

The carbon dioxide emissions from delivered electricity are calculated from the conversion factors shown in Figure A.1. These have been derived from a number of sources including the Building Research Establishment, BREEAM (Building Research Establishment Environmental Assessment Method), Energy Saving Trust, Energy Paper 65 CL scenario (central growth, low fuel price) and Eyre (1990). The level of $CO_2$ has dropped steadily because of greater efficiency, more nuclear and, since 1990, the introduction of combined cycle gas turbines (CCGT). Levels will rise early next century as the Magnox stations are phased out. The conversion factors in Figure A.1 are given in kg $CO_2$/kWh, they are converted to carbon by multiplying by 0.27 (12/44, see Glossary).

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# *APPENDIX B: GLOSSARY*

**Appliances** - the list of appliances covered by the DECADE model is included in detail in Appendix C. This includes lighting and some equipment associated with space and water heating, for instance central heating pumps. All electricity use in the domestic sector is either in DECADE or in BREHOMES (see BRE below).

**Average consumption** - an alternative phrase for the Unit Energy Consumption (see UEC below).

**Ballast** - the circuitry used with a fluorescent or high-intensity discharge light bulb to provide the necessary circuit conditions for starting and operating the light bulb. These may be a separate or an integral part of a lamp. Modern **electronic** ballasts weigh less and operate more quietly than **magnetic** ballasts. They also operate at high frequency which eliminates flicker and increases efficacy, although they tend to be more expensive than magnetic ballasts at present.

**Brown goods** - electronic consumer goods, primarily audio-visual equipment such as TVs, VCRs and music centres. The name comes from the traditional wood casing of the early appliances.

**BRE (Building Research Establishment)** - the research agency funded primarily by the UK Department of the Environment and the creator of BREHOMES.

**Business-as-usual scenario** - a projection of usage and ownership and the underlying rate of technical change determined from historical data where available. The only policy intervention included is that which has been implemented or is close to implementation in the UK or EU, ie energy labels and a 10% efficiency standard for cold appliances implemented in 2000 (passed by the Commission and currently before the EU Parliament), energy labels for wet appliances and subsidies from EST for CFLs.

**Carbon dioxide** - a major greenhouse gas and the main gas produced when fossil fuels are burnt. One molecule ($CO_2$) contains one atom of carbon and two atoms of oxygen, with the relative weights of 12:16:16. Carbon dioxide can be weighed on the basis of either the carbon content (12) or the whole molecule (44). In this report (see Chapter 8) the weight is based on carbon content and given as MtC (million tonnes of carbon). This is the convention now used in government documents.

**CEC (European Commission)** - the civil service of the European Community. Directorate General XVII (Energy) is responsible for the SAVE programme, of which this project is a part.

**Cold appliances** - refrigerators, freezers and combined fridge-freezers.

**CFL (Compact fluorescent lamp)** - A smaller diameter, folded version of traditional fluorescent tubes having an average lifetime of 8000 hours.

**DSM (demand side management)** - policies to reduce the demand for electricity, either in a general sense or, often, as a specific policy of an electricity utility.

**EA (Electricity Association)** - UK organisation representing the 19 electricity companies involved in generation, transmission and distribution of electricity in the UK, and known as the Electricity Council prior to electricity privatisation in 1991.

**EC (European Community)** - the legal body representing the 15 Member States (Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, United Kingdom, and since 1.1.95, Austria, Finland and Sweden).

**Eco labels** - a label assessed on the basis of a complete life cycle analysis. Criteria allow only the best 10 or 20% of products on the market to quality, but the manufacturer has to pay a licence fee to use the eco label logo.

**EIK (Energy improvement kits)** - A study monitoring 25 households undertaken in Birmingham in 1980-1981 by the City Housing Department in collaboration with the Housing Development Directorate of the Department of the Environment.

**Electronic ballast** - see ballast.

**Energy efficiency** - Energy consumed by an operation or series of operations per unit capacity (eg kWh/kg) and per unit of performance.

**ETP (Economic and technical potential)** - ETP is the maximum technical potential which is economically justified to the consumer over the lifetime of an appliance, ie any additional purchase cost is paid back through energy savings. The ETP is based on proven technology, average usage patterns, current EU electricity, water, and equipment prices, with average market mark-ups and an 8% discount rate. It includes no further technical improvement after 2000. If energy or equipment prices change significantly, or if new technologies become available, then the ETP may change. The ETP scenario assumes that all purchases by 2000 fulfil the ETP requirement. It does not include any reduction in consumption from changes in behaviour (eg reduced wash temperatures) and so does not represent the technical limit or the lowest limit on consumption.

**EU (European Union)** - an alternative name to describe group of 15 countries making up the European Community, the EU has no legal status.

**Fluorescent strip light** - a straight tubular fluorescent light bulb containing mercury under low pressure, relative to high-intensity discharge light bulbs. The mercury is ionised by an electric arc, producing ultraviolet energy which, in turn, excites phosphors coating the inside of the light bulb to fluoresce. These lights have an average lifetime of 8000 hours.

**Free drivers** - a free driver changes their intended appliance purchase (say from an average new to best new) because of the publicity surrounding a rebate or loan, but does not take up the rebate or loan.

**Free riders** - a free rider takes up the offer of the rebate or loan, but would have bought the piece of equipment at full price.

**Frost free refrigerator** - a refrigerator with the evaporator located outside the refrigerator compartment. On the running part of the cycle, air is drawn over the evaporator and is blown into the freezer and refrigerator compartments using an electric fan. During the off part of the cycle the evaporator defrosts automatically. The melt water is taken to a pan above the compressor where the heat causes it to evaporate and return to the atmosphere.

**GB (Great Britain)** - the three mainland countries of England, Wales and Scotland (not including Northern Ireland).

**GEA (Group for Efficient Appliances)** - a consortium of researchers from EU national energy agencies, led by the Danes, Dutch and French, and funded by the SAVE programme. The ECU represents the UK in this group. GEA have reported on the cold and wet appliances.

**Halogen (or tungsten halogen) light bulb** - an incandescent light bulb with an encapsulated filament; the capsule contains a halogen gas that reacts with tungsten evaporated from the filament to redeposit it on the filament. These lights have an average lifetime of 2000 hours.

**Half-life** - the half-life of an appliance is the time taken for half the total number of appliances to leave the stock of appliances (interchangeable with average lifetime).

**Hot fill** - washing machines and dishwashers which use hot water heated externally (usually gas-fired) to the machine.

**Household** - this is the same as the census definition: a group of people (who may or may not be related) living, or staying temporarily, at the same address, who have a regular arrangement to share at least one meal daily *or* share common housekeeping. This is the definition used in all official Government publications.

**HEES (Home Energy Efficiency Scheme)** - a government funded scheme to provide basic home energy efficiency improvements, such as loft insulation and draught proofing, for householders on means tested benefit or over 60 years of age.

**Incandescent light bulb** - a light bulb producing visible radiant energy by electrical resistance heating of a filament. These bulbs have an average lifetime of 1000 hours.

**Kilowatt-hour (kWh)** - measure of electrical energy consumed; 1 kWh is equal to 1000 watts used for 1 hour.

**LCD** - liquid crystal display.

**Lifetime** - the average lifetime of an appliance is the time taken for half the total number of appliances to leave the stock of appliances (interchangeable with half-life).

**Lumen** - a measure of light output (the amount of light falling per second on a unit area placed at a distance from a point source).

**Luminaire** - a complete lighting unit consisting of a light bulb or bulbs, together with the parts designed to distribute the light, to position and protect the bulbs, and to connect the bulbs to the power supply. Also referred to as light fixture or fitting.

**LEEP (Lothian and Edinburgh Environmental Partnership**) - LEEP undertook a detailed, two-year survey of 100 low-income households in Edinburgh in 1994-1995 and, in Autumn 1995, started similar work on middle and high-income households. DECADE are supporting these studies and collaborating over the data to be collected.

**Magnetic ballast** - see ballast.

**Minimum standards** - legislation to enforce a minimum level of energy efficiency, a maximum level of energy consumption or the presence or absence of a particular technology.

**Ownership -** the percentage of households owning at least one particular appliance.

**Power demand (watts) -** The SI unit of power, 1 watt = 1 joule of energy for 1 second (J/s), and = work done by 1 ampere at 1 volt.

**Sales-weighted data -** Most analysis to date has been on a simple average of models offered on the market. A better approach would be to weight the analysis according to sales of each model. However, sales data are extremely expensive, and in the case of own brand products, are confidential. The difference between sales weighted analysis and a simple average is assumed to be small where the database is very large, since there tends to be a wide range of brands on offer in popular market sectors. Where the number of models is small, sales weighted data are much more important. Sales weighted data are essential for analysing the effects of policy instruments such as labels, rebates and technology procurement, which might increase the market share of efficient models.

**Specific energy consumption -** Energy consumed per unit of service, given a minimum standard of performance (eg kWh/kg of washed clothing to a given level of cleanliness or kWh/litre of cold space at a specified temperature).

**Standby consumption -** the power demand (W) when an electrical device is either not in use but ready for quick or remote activation (eg a television which has been turned 'off' by remote control) or is offering basic functionality (eg a video displaying a clock, or an answering machine displaying number of recorded messages).

**Stock of appliances -** all the appliances owned by households.

**Takeback -** where improved efficiency is taken in the form of increased level of service, rather than reduced energy consumption.

**Test procedure -** energy used according to defined conditions and international standards (the standards are: EN60456 for washing machines; IEC436 for dishwashers; IEC1121 for tumble dryers; IEC705 for microwaves and EN153 for refrigerators). Essential for comparing models on a similar basis, but difficult to translate into actual consumption. For instance, the test procedure for refrigerators assumes a warm ambient temperature (25ºC) and no door opening. The procedure for washing machines assumes a full load (usually 4 or 5 kg), whereas the average wash may be only half of this. It is further from actual usage for wet appliances since usage varies much more for these appliances than for cold appliances. For brown goods and small appliances, there are no agreed test conditions.

**Transfer function -** a mathematical model for relating one or more input series (cause) to one or more output series (effect), which may be thought of as an extension to linear regression, but allows for time delays and amplification at different frequencies.

**Transformer losses -** the power demand (W) which occurs when a device is switched off but the AC/DC transformer is still in operation because the switch is positioned on the output (DC) side of the transformer rather than on the input (AC) side.

**UEC (Unit energy consumption) -** the annual energy consumption of an average appliance (kWh pa).

**UK (United Kingdom) -** Great Britain plus Northern Ireland.

**Usage patterns** - the way in which an appliance is actually used in the home (for example, for washing machines, the number of washes of different temperatures per year).

**VIP** (Vacuum insulated panels) - A vacuum is a better insulant than conventional foam, though a vacuum is difficult to manufacture and maintain. Recently several manufacturers have developed prototypes of a panel consisting of two plastic sheets sealed round the edges, filled with gel, or glass beads, and evacuated (rather like vacuum packed paté).

**Voluntary agreement -** an agreement with the trade organisation of manufacturers to improve efficiency or reduce consumption of a certain percentage of sales of an appliance by a certain date, perhaps verified by an independent auditor.

**Watt (W) -** unit of active electric power; the rate at which electric energy is used (SI unit = J/s).

**Wet appliances** - clothes washers, tumble dryers, dishwashers.

**White goods** - traditionally the electrical appliances that are found in the kitchen (ie the cold and wet appliances plus large cooking appliances), which usually have white cabinets.

## UNITS OF MEASUREMENT

| | |
|---|---|
| 1 kWh | = 3.6 MJ |
| 1 therm | = $10^5$ Btu |
| 1 therm | = 105.506 MJ |
| 1 therm | = 29.3 kWh |

## POWERS OF TEN

$10^1$ = deca
$10^2$ = hecto
$10^3$ = kilo
$10^6$ = mega
$10^9$ = giga
$10^{12}$ = tera
$10^{15}$ = peta
$10^{18}$ = exa

# APPENDIX C: APPLIANCE CATEGORIES USED IN THE DECADE MODEL

The appliances included in the DECADE study follow the conventions adopted by both the Building Research Establishment and the Electricity Association. The categories include all uses of electricity, apart from space and water heating. The approach ensures that all domestic electricity consumption is included either in DECADE or in the BRE's BREHOMES model. Thus, DECADE includes electric showers and pumps for central heating, whereas BREHOMES includes the energy for heating water that goes into hot-fill appliances.

THIS LIST IS NOT DEFINITIVE AND WILL BE UP-DATED IN LATER ITERATIONS OF THE MODEL.

## C.1 COLD APPLIANCES

REFRIGERATORS: ONE DOOR REFRIGERATORS

FRIDGE-FREEZERS: TWO DOOR COMBINATION REFRIGERATORS (ONE OR TWO COMPRESSORS)

DEEP FREEZERS: ONE DOOR FREEZERS, SUB-DIVIDED INTO CHEST AND UPRIGHT FREEZERS

## C.2 COOKING APPLIANCES

ELECTRIC OVENS: INCLUDING GRILLS

ELECTRIC HOBS

ELECTRIC KETTLES: INCLUDES ALL TYPES OF ELECTRIC KETTLE

MICROWAVES: INCLUDES COMBINATION MICROWAVE/GRILL/CONVECTION OVENS

## C.3 SMALL COOKING APPLIANCES

HOT DRINKS MAKERS: COFFEE AND TEA MAKERS

POP-UP TOASTERS

SANDWICH TOASTERS

DEEP FAT FRYERS

SLOW COOKERS

ELECTRIC FRYING PANS

COOKER HOODS

FOOD PREPARATION APPLIANCES: MIXERS, BLENDERS, PROCESSORS, WHISKS ETC

## C.4 WET APPLIANCES

WASHING MACHINES: ANY WASHING MACHINE INCLUDING THE WASHING CYCLE OF WASHER-DRYERS

TUMBLE DRYERS: ALL TYPES OF DRYERS INCLUDING THE DRYING CYCLE OF WASHER-DRYERS

DISHWASHERS: ALL DISHWASHERS

**C.5 AUDIO-VISUAL**

TELEVISIONS

SATELLITE AND CABLE CONTROL BOXES FOR TVS

VIDEO CASSETTE RECORDERS

NON-PORTABLE AUDIO EQUIPMENT: HI-FI SYSTEMS, MUSIC CENTRES, RECORD PLAYERS ETC

PORTABLE AUDIO EQUIPMENT: CASSETTE RECORDERS, RADIOS ETC

CLOCK RADIOS

**C.6 INTERNAL LIGHTING**

INCANDESCENT: 100W, 60W AND 40W

TUNGSTEN HALOGEN: AN AVERAGE WATTAGE OF 30W

FLUORESCENT STRIP: AN AVERAGE WATTAGE OF 55W

COMPACT FLUORESCENT: AN AVERAGE WATTAGE OF 13.4W

**C.7 MINOR APPLIANCES**

VACUUM CLEANERS

IRONS: STEAM IRONS AND DRY IRONS.

DIY EQUIPMENT: DRILLS, TORCHES, BATTERY CHARGERS ETC

GARDEN EQUIPMENT: LAWN MOWERS, STRIMMERS, HEDGE TRIMMERS ETC

OTHER HOME CARE EQUIPMENT: SEWING MACHINES, FLOOR POLISHERS, LIGHTS ON EXTENSION CORDS ETC

HAIR STYLING: HAIR DRYERS, CURLING TONGS ETC

SMALL PERSONAL CARE APPLIANCES: TOOTHBRUSHES, SHAVERS ETC

ELECTRIC BLANKETS

ELECTRIC TOWEL RAILS

ELECTRIC INSTANTANEOUS SHOWERS

CENTRAL HEATING PUMPS

PERSONAL COMPUTERS

COMPUTER PRINTERS

Facsimile and answering machines

Other office equipment : slide projectors, electric typewriters etc

# *APPENDIX D: MARKET TRANSFORMATION 'TOOLKIT'*

## *DEPARTMENT OF THE ENVIRONMENT*

A 'toolkit' containing essential market transformation language and potential actions to assist a discussion of the issues and the development of strategic initiatives and programmes.

### D.1 RESEARCH

To stimulate an informed debate and provide the basis for effective action.

- **Market analysis,** technical and social research, to reveal market trends and market mechanisms, environmental threats and opportunities and the underlying technical potential for policy.
- **Product differentiation** methodologies eg identification of technical characteristics and/or development of measurement standards, that can be used to identify technically good and bad products - a prerequisite for many effective actions.
- **Consumer research**, to determine scope for changing product design, consumer culture and behaviour and thus improve the effectiveness and balance of policy initiatives.

### D.2 ACTION

Practical ways to help achieve Market Transformation targets.

- **Information** and advice for consumers and retailers eg labelling, accreditation and product lists, to enable rational consumer behaviour and to enhance basic market pull.
- **Promotion** of existing top-end products eg price reductions, vouchers, cash-back and trade-in schemes, to accelerate take-up and to increase market penetration of these products.
- **Procurement** initiatives eg design competitions, Golden Carrot, pre-production sales agreements etc. to help bring forward innovative, improved or lower-priced products, especially where consumer pull is weak or diffuse.
- **Minimum standards** eg European regulations or voluntary agreements, to raise the performance of products at the bottom end of the market, to underpin progress.

November 1995

# APPENDIX E: DECADE STAFF PROFILES

**Dr Brenda Boardman** *(Energy and Environment Programme Leader)*
Dr Brenda Boardman has been PowerGen Fellow in Energy Efficiency at St Hilda's College since October 1991. She specialises in the efficient use of energy in the UK domestic sector, in particular the policy implications and problems faced by low-income households. She is acknowledged as the leading UK researcher on fuel poverty, and is responsible for the concept of affordable warmth. She has published widely and is regularly called upon for expert contributions to conferences, specialist workshops and the UK media. In addition to managing the DECADE project, she has overall responsibility for the Programme's research for the European Commission, Department of the Environment and on rural transport.

**Nick Banks**
Nick Banks is a DPhil student based at the ECU. His research focuses on the cultural factors influencing appliance acquisition and domestic energy use and is closely linked with the work of the DECADE team. Prior to joining ECU, he gained an MSc in Energy Conservation and the Environment from Cranfield University and has recently completed a two year contract for the National Rivers Authority researching best practice for the management of aquatic plants. He is contributing to the behavioural and cultural aspects of the DECADE project.

**Dr Dave Favis-Mortlock**
Dave Favis-Mortlock is developing PRIME as a module for the DECADE model. He has a doctorate on the modelling of soil erosion on UK agricultural land. With a background in Environmental Sciences, and experience of both commercial computer consultancy and lecturing at the University of Brighton, he is also teaching on the Unit's MSc in Environmental Change and Management.

**Dr Mark Hinnells**
Mark Hinnells is responsible for analyses of technical trends in appliances and contributes to policy analysis for market transformation. He supports Geoff Milne on the EU working groups on standby consumption in televisions and videos, and is leading the ECU's collaboration on efficiency of domestic electric storage water heaters. He represented the ECU on the EU Group for Efficient Appliances study of washing machines, dishwashers and dryers. He has a background in Industrial Design with a Masters Degree from Manchester Metropolitan University and has recently completed a PhD on 'Evaluation of environmental impacts of domestic appliances and implications for public policy'.

**Dr Kevin Lane**
Dr Kevin Lane is responsible for developing the DECADE model, and applying it to policy analyses for EU working groups. With a first degree in digital systems and microprocessor engineering, his doctoral research at Lancaster University was on the development and application of non-stationary time series analysis techniques to climatological data. His final project before joining the ECU was the development of the Derwent Water Resources Model (a computer based management model) for the National Rivers Authority.

**Geoff Milne**
Geoff Milne works primarily on housing energy efficiency issues and their impact upon fuel poverty and the environment. He is developing the demographic assumptions for the DECADE scenarios, and is leading the collaboration with NOVEM on the report on standby consumption in televisions and videos for the EU Commission. He has a background in electronics and building services engineering, and has an MSc in Architecture, specialising in environmental and energy studies.

**Jane Palmer**
Jane Palmer graduated with an honours degree in Natural Sciences from Cambridge University and has a background in Genetics. Jane joined the team in July 1995 and works on the analysis of ownership, stock profile and usage data for the DECADE model. She is also responsible for collecting and analysing the lighting data.

**Emma Small**
Emma Small graduated with an honours degree in Natural Sciences from Cambridge University and has a background in Zoology and Psychology. She worked on the analysis of ownership, stock profile and usage data for the DECADE model, and for the Group for Efficient Appliances. Emma left the team in June 1995 and is now studying on the ECU's MSc in Environmental Change and Management.

**Dr Veronica Strang**
Dr Veronica Strang is an anthropologist. Her research focuses on the cultural construction of environmental values, and her brief for the DECADE project is to consider the cultural and behavioural aspects of domestic energy use. Since 1982 she has worked as a writer and consultant on environmental issues (such as the Brundtland Report) in the Caribbean, Australia, Canada and the UK. She has led the ECU's study of consumer responses following the introduction of energy labelling for the cold appliances, which will be published next year as a separate report.

**Joanne Wade**
Joanne Wade has an MSc in Environmental Technology (Energy Policy), and has worked in management consultancy for clients in energy supply industries. In addition to domestic energy use her research interests include the environmental and social impacts of personal transport, and she recently submitted a doctorate on 'Policy instruments to reduce $CO_2$ emissions from European passenger transport: an integrated assessment'. Joanne left the ECU in September 1995 and now works as Research Director at the Association for the Conservation of Energy.

**Temporary staff**

**Nick Blinco** (MSc Ethnology and Museum Ethnography) contributes to the behavioural and cultural aspects of the DECADE project.

**Aless McConville** (MSc Environmental Technology, Energy Policy) worked on data collection and co-ordination.

**Magnus Macfarlane** (MSc International Development Administration and Planning) worked on data collection, particularly for the brown goods.

**Katherine Stenberg** (MSc in Environmental Change and Management) contributed to the research on lighting.

**Consultants**
Dr Mark Barrett, Energy Consultant, Pollen
Horace Herring, Energy Analyst, Bedford Energy Group
Dr Nick Middleton, Editor
Robin Sadler, Energy Consultant, New Perspectives